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UNIVERSITY OF ESWATINI

MAIN EXAMINATION 2019/2020

TITLE OF PAPER: ENVIRONMENTAL CHEMISTRY

COURSE NUMBER: CHE612

TIME ALLOWED: THREE (3) HOURS

INSTRUCTIONS: THERE ARE SIX (6) QUESTIONS IN THIS PAPER. ANSWER QUESTION 1 AND ANY THREE OTHER QUESTIONS (EACH QUESTION IS 20 MARKS)

A PERIODIC TABLE AND OTHER USEFUL DATA HAVE BEEN PROVIDED WITH THIS EXAMINATION PAPER

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QUESTION 1 [40 MARKS]

a) What (describe) molecular or bonding characteristics of water molecules are responsible for the following properties.
   i. Thermal characteristics
   ii. Transmission of light
   iii. Surface tension
   iv. Solvent properties [8]

b) A certain lake has a total volume of 108 m^3. A single river flowing at 2.0 x 10^6 m^3 /day feeds it. Water leaves the lake via several streams, and evaporation is negligible. A nearby factory claims it has been dumping less than 10 kg/day of PVC, this value is the maximum amount permitted by law. The factory owners have refused your request to monitor the effluent discharge from the factory, so you take a sample from the lake and find the concentration of the pollutant to be 10 ppb. Are the factory owners breaking the law? Justify your answer with the appropriate calculations. [5]

c) Water with an alkalinity of of 2.50 x 10^{-3} equivalents/L has a pH of 7.00. given that K_{a1} = 4.45 x 10^{-7} and K_{a2}= 4.69 x 10^{-11}, calculate [CO_2], [HCO_3^-], [CO_3^{2-}], [OH^-] [5]

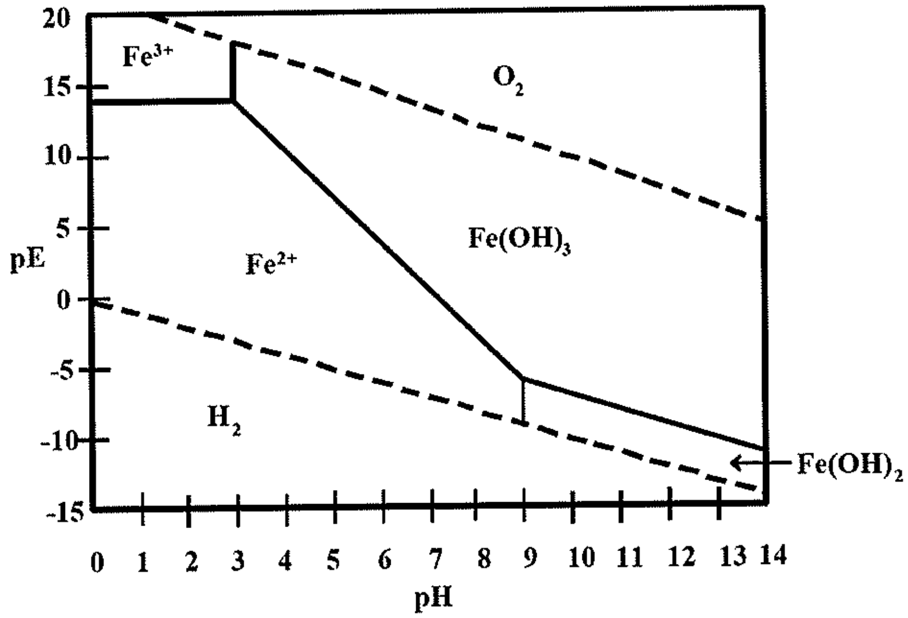
d) Through the photosynthesis activity of algae, the pH of the water in c) above was changed to 9.00. Calculate all the preceding concentrations and weight of biomass {CH_2O} produced, assuming no input of atmospheric CO_2. [9]

e) Draw any ligand that has more than one site for binding to metal ions and identify those sites. [2]

f) If a solution containing initially 30mg/L of trisodium NTA is allowed to come to equilibrium with solid $PbCO_3$ at pH 8.5 in a medium that contains 1.76 x 10^{-3} M HCO_3^- at equilibrium (K = 0.046), what is the value of the ratio of the concentration of NTA bound with lead to the concentration of unbound NTA, [PbT^-]/[HT^{2-}] [3]

g) What detrimental effect may, dissolved, chelating agents have on conventional biological waste treatment? [2]

h) Consider the pE-pH diagram of the Iron system at 10^{-5} M concentration below. Assuming a bicarbonate ion concentration of 1.00 x 10^{-3} M and a value of 3.5 x 10^{-11} for the solubility product of $FeCO_3$, what would you expect to be the stable iron species at pH 9.5 and pE -8.0. [7]



QUESTION 2 [20 MARKS]

a) Using diagrams, examples and or equations write short notes on the Octanol / water partition coefficient, K_{ow}, as applied in environmental chemistry. [8]

b) A model environment has 6 major phases; air, water, soil, sediments, suspended solids and biota. It has an area of 1 km^2 and an atmosphere of 10 km high. Soil to depth of 3 cm covers 30% of the surface, while the rest is covered with water to an average depth of 10m. Water has a 3 cm layer of sediment, contains 5 mL of suspended solids per cubic meter, and 0,5 mLm^{-3} of biota. All phases are homogeneous. 100 moles. Pp-DDT is discharged from a factory to this environment until steady concentrations in each phase are reached at 25°C.

pp-DDT has the following characteristics at 25°C.

K_{sorb} (soil, 2% organic carbon)	1,700
K_{sorb} (sediment, suspend solids, 4% organic carbon)	25,400
K_s (fish, 5% lipid)	77,400
K_{ow}	1,555,000
H	2.3 $mole^{-1}$ m^3 Pa

i. Determine Z values for water, soil, fish and sediment, and suspended solids, respectively. [5]
ii. Establish the overall distribution of the pollutant in this environment using the fugacity concept. [5]
iii. Which phase is DDT dominant, explain. [2]

QUESTION 3 [20 MARKS]

a) Using an example of your choice define the term "risk". [5]
b) You are an environmental consultant and have been asked to conduct a risk assessment on a site on the outskirts of a city selected for domestic housing development. Outline diagrammatically the steps you would take in this evaluation. [15]

QUESTION 4 [20 MARKS]

a) Using any pollutants and sorbents of your choice, write short notes on any two of the following mechanisms of soil sorption as an environmental fate property.
   i. Ligand exchange [5]
   ii. Surface complexation [5]
   iii. Protonation and Ion exchange [5]

b) There has been a spill of 6000L of tetrachloroethylene (PCE, with density of 1.62g/cm^3) to the soil. The ground water table is 5m and the soil is of low permeability. The area of the spill is 20m^2.
   i. Do you expect significant degradation of the tetrachloroethylene? [2]
   ii. Approximately how much will be retained in the unsaturated zone assuming the soil can retain 50L/m^3 [3]
   iii. What will be the fate of the material once it reaches the ground water table? Provide a diagram to illustrate your answer. [5]

QUESTION 5 [20 MARKS]

a) Using short notes compare and contrast advection and dispersion as forms of pollutant transport in aquatic environments. [10]

b) Calculate the average flux (in kg/day) of the pesticide alachlor passing through a point in a river draining a large agricultural basin. The mean concentration of the pesticide is 1.2ug/L, and the mean flow is 60 m^3/s. is this an accurate estimate of the total mass passing this point in a year, considering high runoff events? [10]

QUESTION 6 [20 MARKS]

a) Compare and contrast humic and fulvic acids. In your discussion include genesis reactions, chemical and physical properties, separation (extraction) techniques and any other important similarities/differences. [10]

b) Using examples explain the role of humic/fulvic acids in pollutants transport. In your analysis include the role of functional groups, complexation, binding capacity and its role in oxidation reduction reactions in the aquatic environment. [10]

Total Marks **/100/**

PERIODIC TABLE OF THE ELEMENTS

GROUP NUMBERS IUPAC RECOMMENDATION (1985): 13

GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986): IIIA

ATOMIC NUMBER	RELATIVE ATOMIC MASS (1)
5	10.811
SYMBOL: B	ELEMENT NAME: BORON

PERIOD	GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.008 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.94 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.81 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.085 Si SILICON	15 30.974 P PHOSPHORUS	16 32.06 S SULPHUR	17 35.45 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.38 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.971 Se SELENIUM	35 79.904 Br BROMINE	36 83.798 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.95 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (267) Rf RUTHERFORDIUM	105 (268) Db DUBNIUM	106 (271) Sg SEABORGIUM	107 (272) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (276) Mt MEITNERIUM	110 (281) Ds DARMSTADTIUM	111 (280) Rg ROENTGENIUM	112 (285) Cn COPERNICIUM	113 (285) Nh NIHONIUM	114 (287) Fl FLEROVIUM	115 (289) Mc MOSCOVIUM	116 (291) Lv LIVERMORIUM	117 (294) Ts TENNESSINE	118 (294) Og OGANESSON

LANTHANIDE

57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.05 Yb YTTERBIUM	71 174.97 Lu LUTETIUM

ACTINIDE

89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

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(1) Atomic weights of the elements 2013. Pure Appl. Chem., 88, 265-291 (2016)

TABLE I An abbreviated list of the CODATA recommended values of the fundamental constants of physics and chemistry based on the 2014 adjustment.

Quantity	Symbol	Numerical value	Unit	Relative std. uncert. u_r
speed of light in vacuum	c, c_0	299 792 458	m s^{-1}	exact
magnetic constant	μ_0	$4\pi \times 10^{-7}$	N A^{-2}	
		$= 12.566\,370\,614... \times 10^{-7}$	N A^{-2}	exact
electric constant $1/\mu_0 c^2$	ϵ_0	$8.854\,187\,817... \times 10^{-12}$	F m^{-1}	exact
Newtonian constant of gravitation	G	$6.674\,08(31) \times 10^{-11}$	m^3 kg^{-1} s^{-2}	4.7×10^{-5}
Planck constant	h	$6.626\,070\,040(81) \times 10^{-34}$	J s	1.2×10^{-8}
$h/2\pi$	$\hbar$	$1.054\,571\,800(13) \times 10^{-34}$	J s	1.2×10^{-8}
elementary charge	e	$1.602\,176\,6208(98) \times 10^{-19}$	C	6.1×10^{-9}
magnetic flux quantum $h/2e$	Φ_0	$2.067\,833\,831(13) \times 10^{-15}$	Wb	6.1×10^{-9}
conductance quantum $2e^2/h$	G_0	$7.748\,091\,7310(18) \times 10^{-5}$	S	2.3×10^{-10}
electron mass	m_e	$9.109\,383\,56(11) \times 10^{-31}$	kg	1.2×10^{-8}
proton mass	m_p	$1.672\,621\,898(21) \times 10^{-27}$	kg	1.2×10^{-8}
proton-electron mass ratio	m_p/m_e	1836.152 673 89(17)		9.5×10^{-11}
fine-structure constant $e^2/4\pi\epsilon_0\hbar c$	α	$7.297\,352\,5664(17) \times 10^{-3}$		2.3×10^{-10}
inverse fine-structure constant	α^{-1}	137.035 999 139(31)		2.3×10^{-10}
Rydberg constant $\alpha^2 m_e c/2h$	R_∞	10 973 731.568 508(65)	m^{-1}	5.9×10^{-12}
Avogadro constant	N_A, L	$6.022\,140\,857(74) \times 10^{23}$	mol^{-1}	1.2×10^{-8}
Faraday constant $N_A e$	F	96 485.332 89(59)	C mol^{-1}	6.2×10^{-9}
molar gas constant	R	8.314 4598(48)	J mol^{-1} K^{-1}	5.7×10^{-7}
Boltzmann constant R/N_A	k	$1.380\,648\,52(79) \times 10^{-23}$	J K^{-1}	5.7×10^{-7}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3 c^2$	σ	$5.670\,367(13) \times 10^{-8}$	W m^{-2} K^{-4}	2.3×10^{-6}
		Non-SI units accepted for use with the SI		
electron volt (e/C) J	eV	$1.602\,176\,6208(98) \times 10^{-19}$	J	6.1×10^{-9}
(unified) atomic mass unit $\frac{1}{12}m(^{12}\mathrm{C})$	u	$1.660\,539\,040(20) \times 10^{-27}$	kg	1.2×10^{-8}

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