UNIVERSITY OF ESWATINI

MAIN EXAMINATION 2020/21

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 QUESTIONS (EACH QUESTION IS 20 MARKS)

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

PLEASE DO NOT OPEN THIS PAPER UNTIL AUTHORISED TO DO SO BY THE CHIEF INVIGILATOR.

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) Exactly 45.359 kg of cane sugar (dextrose), $C_{12}H_{22}O_{11}$, were accidentally discharged into a small stream saturated with Oxygen from the air at 25°C. How many liters of water could be contaminated to the extent of removing all the dissolved oxygen by biodegradation? [5]

c) Water with an alkalinity of of 2.00×10^{-3} equivalents/L has a pH of 7.00. calculate $[CO_2]$, $[HCO_3^-]$, $[CO_3^{2-}]$, $[OH^-]$ [5]

d) Through the photosynthesis activity of algae, the pH of the water in b) above was changed to 10.00. 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 25mg/L of trisodium NTA is allowed to come to equilibrium with solid $PbCO_3$ at pH 8.5 in a medium that contains 11.76×10^{-3} M $HCO3^-$ 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. Assuming a bicarbonate ion concentration of 1.00×10^{-3} M and a value of 3.5×10^{-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
   i. Octanol / water partition coefficient, Kow, as applied in environmental chemistry. [10]
   ii. Bioaccumulation [10]

In each highlight the environmental relevance, methods of determination and where applicable give methods of estimation using Quality Structure Activity Relationships (QSAR's).

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 2000L of tetrachloroethylene (PCE) to the soil. The ground water table is 5m and the soil is of low permeability. The area of the spill is $25m^2$.

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 $40L/m^3$ [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 basis. The mean concentration of the pesticide is 1.0ug/L, and the mean flow is 50 m^3/s. is this an accurate estimate of the total mass passing this point in a year, considering high runoff events? [10]

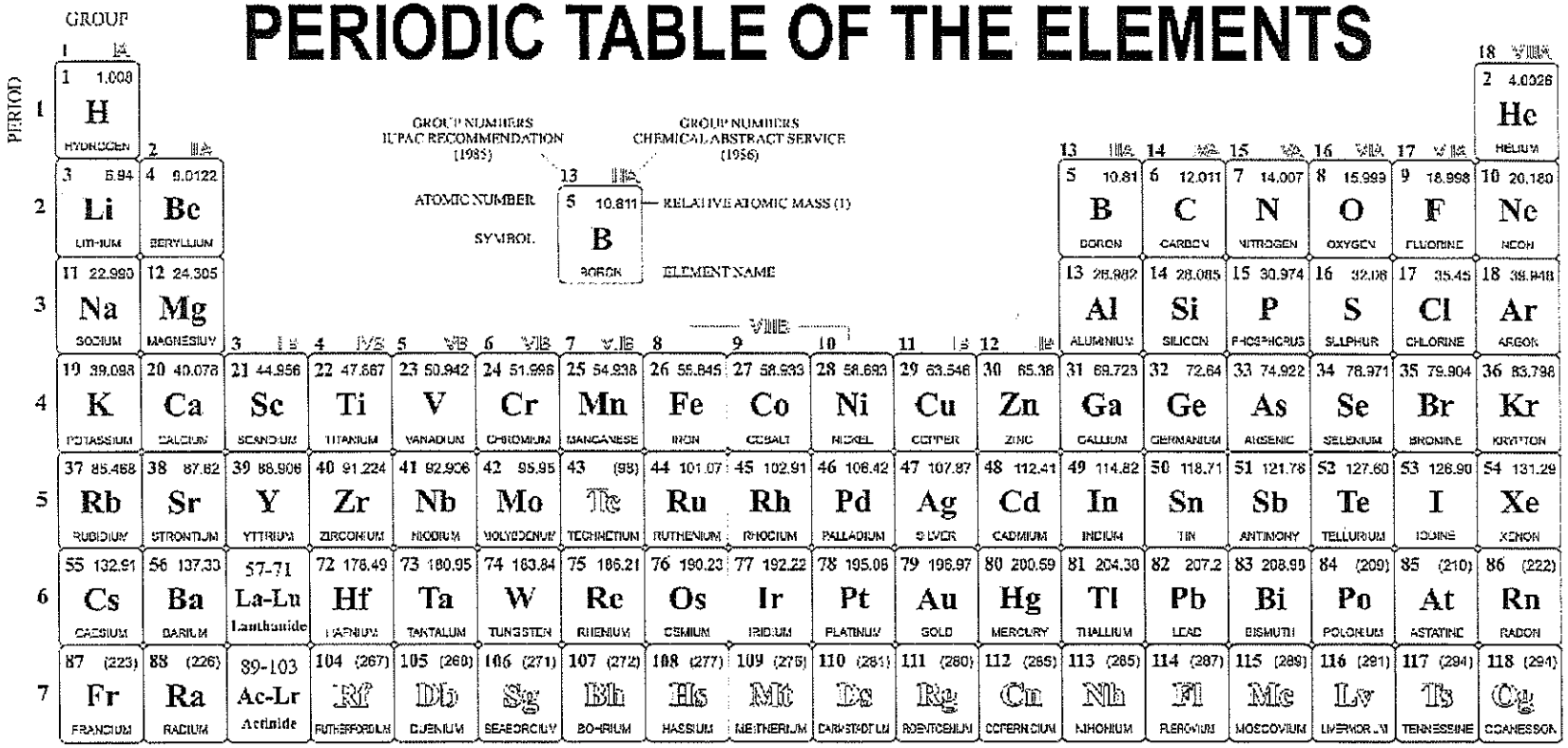
QUESTION 6 [20 MARKS]

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



www.pentoni.com

(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	$\mathrm{m\ s^{-1}}$	exact
magnetic constant	μ_0	$4\pi \times 10^{-7}$	$\mathrm{N\ A^{-2}}$	
		$= 12.566\,370\,614... \times 10^{-7}$	$\mathrm{N\ A^{-2}}$	exact
electric constant $1/\mu_0 c^2$	ϵ_0	$8.854\,187\,817... \times 10^{-12}$	$\mathrm{F\ m^{-1}}$	exact
Newtonian constant of gravitation	G	$6.674\,08(31) \times 10^{-11}$	$\mathrm{m^3\ kg^{-1}\ s^{-2}}$	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)	$\mathrm{m^{-1}}$	5.9×10^{-12}
Avogadro constant	N_A, L	$6.022\,140\,857(74) \times 10^{23}$	$\mathrm{mol^{-1}}$	1.2×10^{-8}
Faraday constant $N_A e$	F	96 485.332 89(59)	$\mathrm{C\ mol^{-1}}$	6.2×10^{-9}
molar gas constant	R	8.314 4598(48)	$\mathrm{J\ mol^{-1}\ K^{-1}}$	5.7×10^{-7}
Boltzmann constant R/N_A	k	$1.380\,648\,52(79) \times 10^{-23}$	$\mathrm{J\ K^{-1}}$	5.7×10^{-7}
Stefan-Boltzmann constant $(\pi^2/60)k^4/\hbar^3 c^2$	σ	$5.670\,367(13) \times 10^{-8}$	$\mathrm{W\ m^{-2}\ K^{-4}}$	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}