UNIVERSITY OF SWAZILAND

Faculty of Health Science

Department of Environmental Health Sciences

Main Examination 2010

Title of paper: INSTRUMENTAL METHODS FOR ENVIRONMENTAL ANALYSIS 1

Course code: EHS 573

Time allowed: 2 hours

Marks allocation: 100 Marks

Instructions:

1) Write neatly and clearly
2) Answer **ANY FOUR (4)** questions
3) Each question carries **25** marks
4) Begin each question in a separate sheet of paper
5) A periodic table and other useful data has been provided

This paper is not to be opened until the invigilator has granted permission

Question 1(25 marks)

(a) Distinguish between classical and instrumental methods of analysis. [2]

(b) What are the unique advantages of instrumental methods of analysis over the classical methods? [4]

(c) List the principal classes of chemical instrumentation. Give two specific examples of instrumental techniques from each principal class given. [6]

(d) Using a labeled diagram, show the basic components of an instrument for chemical/environmental analysis. Discuss the functions of any one of the components and give an example in named equipment. [8]

(e) List the salient performance characteristics of an instrument for environmental analysis. [5]

Question 2 (25 marks)

(a) Define the following terms: '**Transmittance' and 'Absorbance**'. Obtain a relationship between the two of them. [3]

(b) Discuss very briefly, the effects of a medium's refractive index on the wavelength, velocity and frequency of a radiation passing through the medium. [3]

[c] The wavelength of the sodium D line is 589 nm.
- (i) Calculate its frequency, wave-number and energy.
- (ii) Suppose another line is observed at a wavelength of 450nm. Is this line of a higher energy than the sodium D line (at 589 nm)? [11]

(d) A biological sample with an active ingredient, X (F.W. = 270), has a molar absorptivity, ϵ, of 703 $M^{-1}cm^{-1}$ at a wavelength of 262nm. A given amount of the sample was dissolved with water in a 5L volumetric flask and then made to the mark. A 1.00-cm cell was used to measure the absorbance of the solution at 262nm,and a reading of 0.275 was obtained. Calculate the amount of X (in grammes), present in the sample. [8]

Question 3 (25 marks)

(a) What is a spectrophotometer? State four of its basic components and their functions respectively. [8]

(b) What is the requirement for a cell material before it can be used for a particular spectral region? [1]

(c) Give two examples of materials generally used for each of the following regions:
(i) UV & Visible; (ii) IR [4]

(d) In respect of 'A Mull' and 'A KBr Pellet' used during spectroscopic analysis:

(i) State the nature of samples for which they are used and their respective spectral regions of application. [2]

(ii) Briefly describe how they are prepared. [6]

(e) What are the necessary precautionary measures that need be taken when using a cell during a UV-Visible spectroscopic analysis? Why are these measures crucial? [4]

Question 4 (25 marks)

(a) What is a monochromator? [2]

(b) For a spectrophotometer, list the components of a monochromator system and state the respective functions of each component given. [7]

(c) For each of the following spectral regions, suggest an appropriate monocromator prism material :
(i) Visible (ii) UV (iii) IR
Give an appropriate reason for your choice. [4]

(d) What are the advantages and disadvantages of "diffraction gratings" when compared with a "glass prism" as monochromators for spectrophotometers? [4]

(e)

(i) Explain the term 'dispersion of a prism'. Hence, briefly describe the working principles of a prism as a monochromator.

(ii) List the factors that increase the resolution of a 'prism' and 'diffraction gratings' [8]

Question 5 (25 marks)

(a) Explain the term 'source' with regards to atomic spectroscopic methods. Give two examples and state four of its ideal goals. [7]

(b) Discuss the major limitations of atomic spectroscopic methods. [2]

(c) For the flame atomic absorption spectrophotometry (FAAS) :

(i) What analyte property is measured and in what units ? [2]

(ii) Draw and label a schematic diagram of the 'atomic absorption spectrophotometer' [4]

(iii) Briefly describe its working principles.. [8]

(iv) Give four examples of environmental pollutants it can be used to analyze. [2]

Question 6(25 marks)

The hollow cathode lamp is a vital primary source of radiation in atomic absorption spectrometry. Discuss:

(a) Its features as a sharp line radiation source. [3]

(b) Its structure (configuration) plus a schematic diagram of it. [7]

(c) Its working principles. [10]

(d) The composition and short comings of multielement hollow cathode lamps. [6]

(e) The essence of the cylindrical structure of the cathode tube. [2]

General data and fundamental constants

Quantity	Symbol	Value
Speed of light†	c	$2.997\,924\,58 \times 10^{8}$ m s^{-1}
Elementary charge	e	$1.602\,177 \times 10^{-19}$ C
Faraday constant	$F = eN_A$	9.6485×10^{4} C mol^{-1}
Boltzmann constant	k	$1.380\,66 \times 10^{-23}$ J K^{-1}
Gas constant	$R = kN_A$	$8.314\,51$ J K^{-1} mol^{-1}
		$8.205\,78 \times 10^{-2}$ dm^{3} atm K^{-1} mol^{-1}
		62.364 L Torr K^{-1} mol^{-1}
Planck constant	h	$6.626\,08 \times 10^{-34}$ J s
	$\hbar = h/2\pi$	$1.054\,57 \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\,14 \times 10^{23}$ mol^{-1}
Atomic mass unit	u	$1.660\,54 \times 10^{-27}$ kg
Mass of electron	m_e	$9.109\,39 \times 10^{-31}$ kg
proton	m_p	$1.672\,62 \times 10^{-27}$ kg
neutron	m_n	$1.674\,93 \times 10^{-27}$ kg
Vacuum permeability†	μ_0	$4\pi \times 10^{-7}$ J s^{2} C^{-2} m^{-1}
		$4\pi \times 10^{-7}$ T^{2} J^{-1} m^{3}
Vacuum permittivity	$\varepsilon_0 = 1/c^2\mu_0$	$8.854\,19 \times 10^{-12}$ J^{-1} C^{2} m^{-1}
	$4\pi\varepsilon_0$	$1.112\,65 \times 10^{-10}$ J^{-1} C^{2} m^{-1}
Bohr magneton	$\mu_B = e\hbar/2m_e$	$9.274\,02 \times 10^{-24}$ J T^{-1}
Nuclear magneton	$\mu_N = e\hbar/2m_p$	$5.050\,79 \times 10^{-27}$ J T^{-1}
Electron g value	g_e	$2.002\,32$
Bohr radius	$a_0 = 4\pi\varepsilon_0\hbar^2/m_e e^2$	$5.291\,77 \times 10^{-11}$ m
Rydberg constant	$R_\infty = m_e e^4/8h^3c\varepsilon_0^2$	$1.097\,37 \times 10^{5}$ cm^{-1}
Fine structure constant	$\alpha = \mu_0 e^2 c/2h$	$7.297\,35 \times 10^{-3}$
Gravitational constant	G	$6.672\,59 \times 10^{-11}$ N m^{2} kg^{-2}
Standard acceleration of free fall†	g	$9.806\,65$ m s^{-2}

† Exact (defined) values

Prefixes

f	p	n	μ	m	c	d	k	M	G
femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}

PERIODIC TABLE OF ELEMENTS

GROUPS

PERIODS	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1.008 H 1																	4.003 He 2
2	6.941 Li 3	9.012 Be 4											10.811 B 5	12.011 C 6	14.007 N 7	15.999 O 8	18.998 F 9	20.180 Ne 10
3	22.990 Na 11	24.305 Mg 12											26.982 Al 13	28.086 Si 14	30.974 P 15	32.06 S 16	35.453 Cl 17	39.948 Ar 18
4	39.098 K 19	40.078 Ca 20	44.956 Sc 21	47.88 Ti 22	50.942 V 23	51.996 Cr 24	54.938 Mn 25	55.847 Fe 26	58.933 Co 27	58.69 Ni 28	63.546 Cu 29	65.39 Zn 30	69.723 Ga 31	72.61 Ge 32	74.922 As 33	78.96 Se 34	79.904 Br 35	83.80 Kr 36
5	85.468 Rb 37	87.62 Sr 38	88.906 Y 39	91.224 Zr 40	92.906 Nb 41	95.94 Mo 42	98.907 Tc 43	101.07 Ru 44	102.91 Rh 45	106.42 Pd 46	107.87 Ag 47	112.41 Cd 48	114.82 In 49	118.71 Sn 50	121.75 Sb 51	127.60 Te 52	126.90 I 53	131.29 Xe 54
6	132.91 Cs 55	137.33 Ba 56	138.91 *La 57	178.49 Hf 72	180.95 Ta 73	183.85 W 74	186.21 Re 75	190.2 Os 76	192.22 Ir 77	195.08 Pt 78	196.97 Au 79	200.59 Hg 80	204.38 Tl 81	207.2 Pb 82	208.98 Bi 83	(209) Po 84	(210) At 85	(222) Rn 86
7	223 Fr 87	226.03 Ra 88	(227) **Ac 89	(261) Rf 104	(262) Ha 105	(263) Unh 106	(262) Uns 107	(265) Uno 108	(266) Une 109	(267) Uun 110								

Atomic mass → 10.811
Symbol → B
Atomic No. → 5

TRANSITION ELEMENTS

*Lanthanide Series	140.12 Ce 58	140.91 Pr 59	144.24 Nd 60	(145) Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.93 Tb 65	162.50 Dy 66	164.93 Ho 67	167.26 Er 68	168.93 Tm 69	173.04 Yb 70	174.97 Lu 71
**Actinide Series	232.04 Th 90	231.04 Pa 91	238.03 U 92	237.05 Np 93	(244) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103

( ) indicates the mass number of the isotope with the longest half-life.