Birla Institute of Technology and Science Pilani (Rajasthan)
CHEM F414: Bio and Chemical Sensors

Comprehensive Exam	**Closed Book**	**II Semester 2022-23**
Max. Marks: 30	**Time: 60 minutes**	**Date: 06. 05. 2023**

Q. 1(a) Explain the mechanism of light emission by quantum-dot fluorescence. **(2)**

(b) Write the mechanism of QD chemiluminescence involving hydrogen peroxide as a source of electron donors and acceptors. **(2)**

(c) What are the differences between metallic and semiconductor SWCNTs? What are the advantages of using CNTs for sensor applications? **(2)**

(**d)** What are the optical phenomena that occur when a light beam crosses a colloidal solution of metal nanoparticles? **(2)**

(e) Explain the use of porous silicon for optical sensing. **(2)**

(f) Why dendrimer structures are of interest to the development of chemical sensors. **(2)**

(g) Write the expression for absorbance in an evanescent field and how is it different from normal spectrophotometry. **(2)**

(h) Explain the advantages of Raman spectroscopy in optical sensing. **(1)**

Q.2 (a) Derive an expression that defines cone of acceptance for an optical fiber. **(2)**

(b) What are the similarities and differences between optical and electrochemical selectivity? **(2)**

(c) What is the challenge associated with liquid optical sensing and how to overcome it? **(2)**

(d) What is the difference between specular and diffuse reflectance? **(1)**

(e) Explain the thought experiment II of electrochemical sensors. **(2)**

(f) How charge transfer resistance of an electrochemical sensor is determined? **(2)**

(g) What are Tafel plots. **(2)**

(h) Explain the construction of glass membrane type ion selective electrode. **(2)**

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Max. Marks: 50	**Time: 120 minutes**	**Date: 06. 05. 2023**

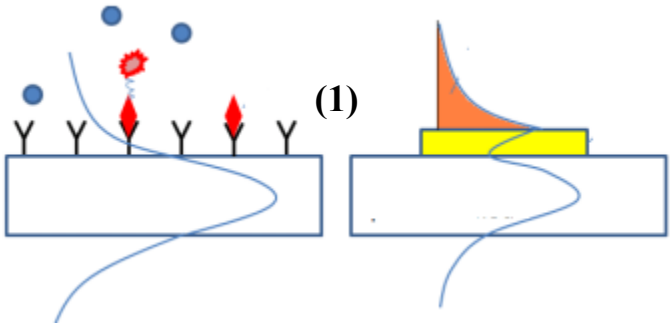
Note: There are **two** questions printed on two pages, answer all parts of a question together.

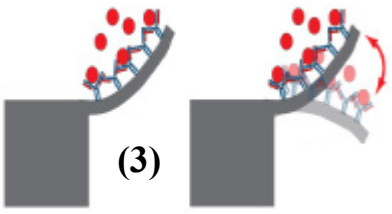
Q. 1 (a) Draw the table in the answer sheet and fill the method/features. **(4)**

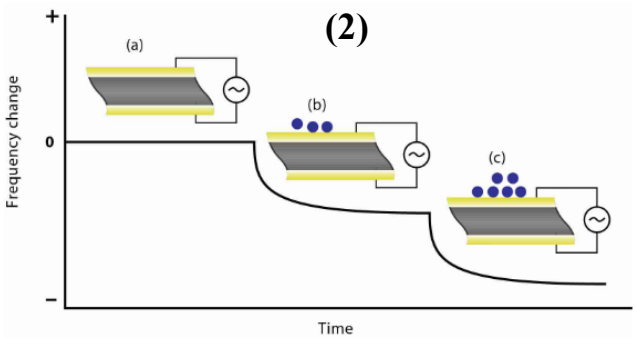
S. No.	Method/Feature	Support Material			
		Cotton fibers	Cyanuric chloride	Hexamethyl -diisocynate	Polypyrrole
1	Immobilization method				
2	Preparation (Easy/Difficult)				
3	Enzyme activity (Low/High)				
4	Substrate specificity (Changeable/unchangeable)				
5	Binding force (Weak/strong)				
6	Regeneration (Possible/Impossible)				

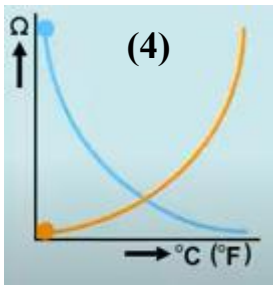
(b) What are the key assumptions in the Michaelis–Menten mechanism? For an enzyme with K_M of 0.5mM determine at what substrate concentration will the velocity of the enzyme reach 1/4 of the V_{max}? V_{max} = 200 mmol. **(4)**

(c) Explain the sensing principles described in Figure (1-4). **(12)**









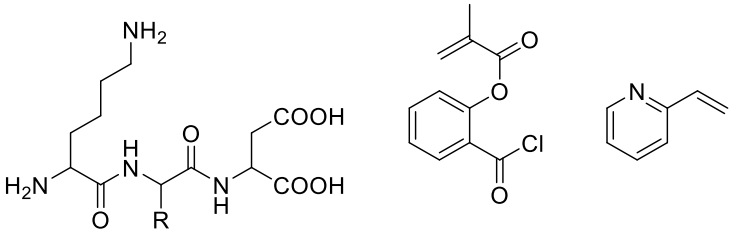
(d) What kind of chemical reaction can be used in sensors for combustible gases and what physical effects of the reaction form the basis of the transduction principle in such sensors? **(3)**

(e) Why does the ratio of anti-Stokes to Stokes intensities increase with sample temperature? **(2)**

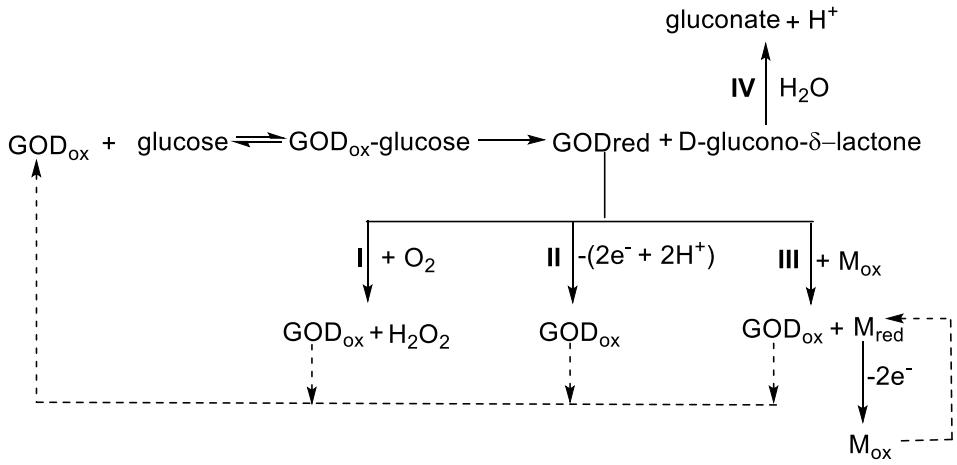
Q. 2 (a) The molar absorption coefficients of two substances A and B at two wavelengths (1 and 2) are as follows: ε_{A1} = 14190 $M^{-1}cm^{-1}$, ε_{B1} = 3349 $M^{-1}cm^{-1}$, ε_{A2} = 3453 $M^{-1}cm^{-1}$, ε_{B2} = 5556 $M^{-1}cm^{-1}$. The total absorbances of a solution at these two wavelengths in a cell of length 1.0 cm were measured as 1.01 and 0.870, respectively. What are the molar concentrations of A and B in the solution? **(4)**

(b) Design a photoelectrochemical immunosensor with Doxorubicin dye (encapsulated in alginate) showing enhanced anodic photocurrent response for detection of SARS COV-2 spike protein using europium-doped TiO_2 coated onto indium tin oxide electrode. **(4)**

(c) From the molecules given make imprinted polymer using both covalent and non-covalent approaches. **(4)**



(d) Write the possible transduction methods (I-IV) for glucose oxidase-based sensors shown below. **(4)**



(e) Give a derivation of the Stern–Volmer equation using the chemical kinetics approach assuming that the concentration of the excited state is constant. **(4)**

$F + h\nu \xrightarrow{k_{abs}} {}^1F^*$ Excitation

${}^1F^* \xrightarrow{k_{ic}} F + \text{heat}$ Internal conversion

${}^1F^* \xrightarrow{k_f} F + h\nu'$ Fluorescence

${}^1F^* + Q \xrightarrow{k_q} F + Q'$ Quenching

(f) (i) The Butler-Volmer equation follows as:

$$i_{total} = i_0\left(\exp\left(\frac{-\alpha F\eta}{RT}\right) - \exp\left(\frac{(1-\alpha)F\eta}{RT}\right)\right)$$

Show that for small values of η, i vs. η is linear. **(2)**

(ii) Calculate k^0, if the exchange current density for Pt/$Fe(CN)_6^{3-}$ (2.0 mM), $Fe(CN)_6^{4-}$ (2.0 mM), NaCl (1.0 M) at 25 ºC is 2.0 mA/cm^2, α for this system is 0.50. **(3)**

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