THE OPEN UNIVERSITY OF SRI LANKA

B. Sc. Degree Programme — Level 4
Assignment I (Test) — 2011/2012
CMU 2220 — Concepts in Chemistry

1 hour

4. 00 p.m. – 5.00 p.m. 28th September 2011 (Wednesday)

- Answer all 25 questions (25 x 4 = 100 marks)
- Choose the most correct answer to each of the questions and mark this answer with an "X" on the answer script in the appropriate box.
- Use a **PEN** (not a PENCIL) in answering.
- Any answer with more than **one** "X" marked will be considered as an *incorrect* answer.
- Marks will be deducted for incorrect answers (0.6 per incorrect answer).
- The use of a non-programmable electronic calculator is permitted.
- Cellular phones are **not** allowed.

Gas constant (R)	=	$8.314\ JK^{-1}mol^{-1}$
Avogadro constant (N_A)	=	$6.023\times10^{23}\ mol^{-1}$
Faraday constant (F)	=	$96,500\ Cmol^{-1}$
Planck constant (h)	=	$6.63\times10^{-34}\ Js$
Velocity of light (c)	=	$3.0\times10^{8}\ ms^{-1}$
Standard atmospheric pressure	=	$10^5\ Pa\left(Nm^{-2}\right)$
$Log_e(X)$	=	$2.303\ Log_{10}(X)$

1. Molecular spectroscopy is used in the determination of the

   (i) molecular geometry.

   (ii) molecular weight.

   (iii) dipole moment of a molecule.

   The correct statements out of (i), (ii) and (iii) above are
   (a) Only (i) and (ii). (b) Only (i) and (iii). (c) Only (ii) and (iii).
   (d) All (i), (ii) and (iii) (e) None of the answers (a), (b), (c) or (d) is correct.

2. Which of the following statements best describes the Bohr condition in spectroscopy?

   (a) The energy of a molecule is quantised.

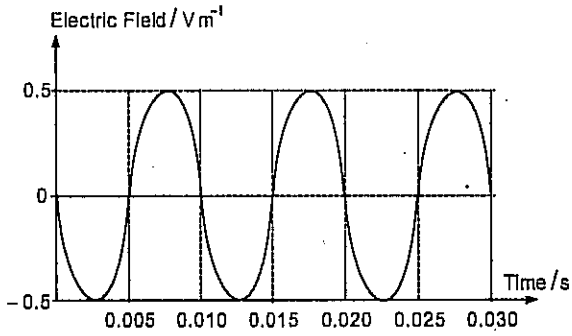
   (b) Absorption of photons by a molecule is determined by selection rules.

   (c) The energy of a photon absorbed by a molecule is equal to the difference in two energy levels of the molecule.

   (d) The energy of a photon absorbed by a molecule is equal to the difference in energy of the two energy levels involved in the transition brought about by the absorption process.

   (e) An excited hydrogen atom may come back to the ground state by the emission of a photon.

3. The variation of the electric field strength at a particular point in a beam of monochromatic radiation as a function of time is shown in the following figure.

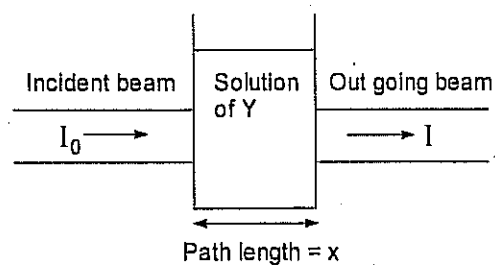


What is the frequency of the radiation?

(a) 2 Hz (b) 1 Hz (c) 100 Hz
(d) 200 Hz (e) 50 Hz

Use the following data in answering questions 4 – 7.

A student placed a sample of an aqueous solution of a chemical compound Y in the monochromatic beam of radiation of frequency ν, in an absorption spectrometer, in a sample tube of path length x; see the figure. The concentration of Y in the solution was $0.05\ \text{mol dm}^{-3}$. The molar extinction coefficient of Y at frequency ν was $5.0\ \text{dm}^3\ \text{mol}^{-1}\ \text{cm}^{-1}$. The cross sectional area of the incident and out going beams was $2.5\times10^{-4}\ \text{m}^2$. The number of photons passing through a cross section of the incident and out going beams in 2 seconds were 3.0×10^{15} and 1.5×10^{15}, respectively. The intensity, I, of the out going beam was $4.5\times10^{-5}\ \text{W m}^{-2}$.



4. What is the frequency, ν, of the monochromatic radiation?

(a) 2.26×10^{13} Hz (b) 2.26×10^{12} Hz (c) 2.26×10^{11} Hz
(d) 2.26×10^{10} Hz (e) 2.26×10^{9} Hz

5. What is the transmittance of the sample?

(a) 0.5 (b) 0.4 (c) 0.3
(d) 2.0 Hz (e) 1.5

6. What is the absorbance of the sample?

(a) 0.03 (b) 0.01 (c) 0.02
(d) 0.2 Hz (e) 0.3

7. What is the path length, x?

(a) 1.2 cm (b) 2.4 cm (c) 1.0 cm
(d) 2.0 cm (e) 2.5 cm

8. What do you understand by the term **"number density"** of a beam of electromagnetic radiation?

(a) The number of photons passing a cross session of a beam in one second.

(b) The number of photons passing a cross session of a beam.

(c) The total number of photons in a beam.

(d) The number of photons passing through a unit volume of a beam of radiation in one second.

(e) The number of photons in a unit volume of a beam of radiation.

9. What are the factors that affect the molar absorption coefficient of a chemical species in solution?

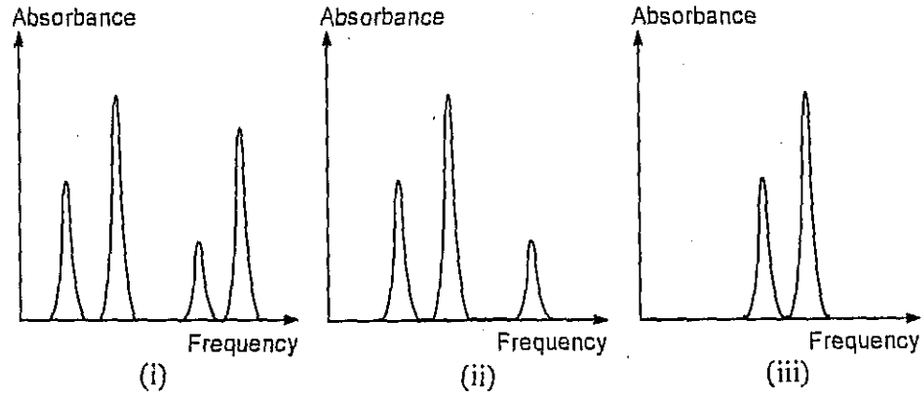
(i) The temperature of the sample

(ii) The wavelength of radiation

(iii) The solvent

The correct statements out of (i), (ii) and (iii) above are
(a) Only (i) and (ii). (b) Only (i) and (iii). (c) Only (ii) and (iii).
(d) All (i), (ii) and (iii) (e) None of the answers (a), (b), (c) or (d) is correct.

10. A particular (hypothetical) molecule has only three energy levels. Out of the following what are the spectra that may have been generated using a sample of these molecules?



(a) Only (i) and (ii). (b) Only (i) and (iii). (c) Only (ii) and (iii).
(d) All (i), (ii) and (iii) (e) None of the answers (a), (b), (c) or (d) is correct.

11. As usual the j^{th} electronic, vibrational and rotational energy levels of a molecule are designated by e_j, V_j and R_j respectively. During the absorption of a photon, a molecule gets excited from energy level E_2 to E_3 where $E_2 = e_1 + V_2 + R_3$ and $E_3 = e_1 + V_3 + R_2$. Out of the following, what type of energy transition/s of the molecule is/are associated with the absorption of the above mentioned photon?

(i) Electronic (ii) Vibrational (iii) Rotational

(a) Only (i). (b) Only (ii) (c) Only (iii).
(d) Only (i) and (ii) (e) Only (ii) and (iii).

12. In standard notation the Boltzmann distribution is given by $\frac{N_i}{N_j} = \frac{g_i}{g_j} \exp\left(-\frac{E_i - E_j}{kT}\right)$.

It was found that in a sample of a heterogeneuos diatomic molecule, XY, the population of the 4^{th} excited state, in units of moles, is given by $N_4 = 4 \exp\left(-\frac{E_4 - E_0}{kT}\right)$ at a particular temperature T. It is known that the population of the ground state (whose energy is E_0) in the sample is 1 mol and the ground state is doubly degenerate. What is the degeneracy of the 4^{th} excited state of the molecule?

(a) 2 (b) 4 (c) 6
(d) 8 (e) 10

13. What is the decreasing order of dipole moment of the following molecules?

(A) o-dinitro benzene (B) m-dinitro benzene (C) p-dinitro benzene

(a) A > B > C (b) B > A > C (c) C > B > A
(d) A > C > B (e) C > A > B

14. Which of the following molecules may show an induced dipole moment when placed in an electric field?

(i) CO_2 (ii) ICl (iii) CO

(a) Only (i) and (ii). (b) Only (i) and (iii). (c) Only (ii) and (iii).
(d) All (i), (ii) and (iii) (e) None of the answers (a), (b), (c) or (d) is correct.

15. Consider the following statements on radiation sources used in spectrometers.

(i) A Nernst filament is used to generate radiation in IR-region.

(ii) A Klystron is used to generate radiation in UV-region.

(iii) A Tungston/Iodine lamp is used to generate radiation in visible region.

The correct statements out of (i), (ii) and (iii) above are

(a) Only (i) and (ii). (b) Only (i) and (iii). (c) Only (ii) and (iii).
(d) All (i), (ii) and (iii) (e) None of the answers (a), (b), (c) or (d) is correct.

16. The width of a peak in a spectrum of a sample of molecules may be determined by

(i) Doppler broadening

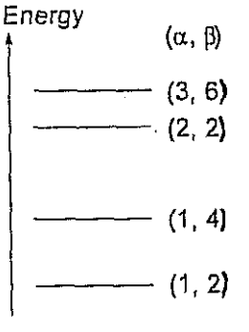
(ii) Lifetime broadening

(iii) Temperature of the sample.

The correct statements out of (i), (ii) and (iii) above are

(a) Only (i) and (ii). (b) Only (i) and (iii). (c) Only (ii) and (iii).
(d) All (i), (ii) and (iii) (e) None of the answers (a), (b), (c) or (d) is correct.

17. A molecule has only three energy levels which are labelled by two quantum numbers, (α, β). The four energy levels have the labels $(1,2)$, $(1,4)$, $(2,2)$ and $(3,6)$; see the figure. The selections rules in absorption spectroscopy are $\Delta\alpha = +1$ and $+2$ and $\Delta\beta = \pm 2$. What is the maximum number of lines that may be observed in the full absorption spectrum of a sample of these molecules?



(a) 1 (b) 2 (c) 3
(d) 4 (e) 5

Use the following data in answering questions 18 and 19.

The reaction, $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, is an elementary reaction.

18. The rate of the above given reaction is proportional to

(a) $[N_2][H_2]$ (b) $[N_2]^3[H_2]$ (c) $[N_2][H_2]^3$
(d) $[N_2][3H_2]$ (e) $[NH_3]^2$

19. Consider the following statements about the above given elementary reaction.

(i) The molecularity of the reaction is three.

(ii) The order of the reaction with respect to $N_2(g)$ is one.

(iii) The overall order of the reaction is four.

The correct statements out of (i), (ii) and (iii) above are

(a) Only (i) and (ii). (b) Only (i) and (iii). (c) Only (ii) and (iii).
(d) All (i), (ii) and (iii) (e) None of the answers (a), (b), (c) or (d) is correct.

20. Consider the rate law, $\frac{d[A]}{dt} = k[A][B]^{2/3}$. The units of k is

(a) $mol^{-1}\,dm^3\,s^{-1}$ (b) $mol^{-2/3}\,dm^2\,s^{-1}$ (c) $mol^{-5/3}\,dm^{-6}\,s^{-1}$
(d) $mol^{-2/3}\,dm^{-2}\,s^{-1}$ (e) $mol^{2/3}\,dm^{-2}\,s^{-1}$

21. The reaction, $A \rightarrow$ Products, is a first order reaction. At a particular temperature, the rate constant for the above reaction is $2\times10^{-2}\,min^{-1}$. What is the best approximation for the half-life of the reaction if the initial concentration of A is $0.50\,mol\,dm^{-3}$?

(a) 2 s (b) 1 s (c) 70 min
(d) 15 min (e) 35 min

22. The rate law of the overall reaction $A+2B \rightarrow C$ is given by $Rate = k[A][B]$. If the reaction proceeds by a two step process, then the rate determining step is likely to be of the form

(a) $A+A \rightarrow$ intermediate (b) $B+B \rightarrow$ intermediate (c) $2B \rightarrow C$
(d) $A+B \rightarrow$ intermediate (e) $A+B+C \rightarrow$ intermediate

23. For a reversible first order reaction of the form, $A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} B$, the rate equation can be written as

(a) $-\frac{d[A]}{dt} = k_1[A] - k_{-1}[B]$

(b) $\frac{d[A]}{dt} = k_1[A] - k_{-1}[B]$

(c) $\frac{d[B]}{dt} = -k_1[A] - k_{-1}[B]$

(d) $\frac{d[B]}{dt} = k_1[A] + k_{-1}[B]$

(e) $\frac{d[B]}{dt} = 0$

24. Consider the following statements about the reversible reaction, $A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} B$, which is first order in both directions. Here, k_1 and k_{-1} are the rate constants of the forward and the backward reactions respectively.

(i) At equilibrium, the rate of the forward reaction is equal to the rate of the reverse reaction.

(ii) At equilibrium, the concentrations of A and B become equal.

(iii) The equilibrium constant is equal to $\frac{k_1}{k_{-1}}$.

The correct statements out of (i), (ii) and (iii) above are

(a) Only (i) and (ii). (b) Only (i) and (iii). (c) Only (ii) and (iii).
(d) All (i), (ii) and (iii) (e) None of the answers (a), (b), (c) or (d) is correct.

25. Consider the following mechanism which is used to describe the decomposition of a gaseous molecule, A.

$$A + A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} A + A^*$$

$$A^* \xrightarrow{k_2} \text{Products}$$

The expression that best represents the rate of change of concentration of A^* is

(a) $\dfrac{d[A^*]}{dt} = k_1[A]^2 - k_{-1}[A][A^*] - k_2[A^*]$

(b) $\dfrac{d[A^*]}{dt} = k_{-1}[A]^2 - k_1[A][A^*] - k_2[A^*]$

(c) $\dfrac{d[A^*]}{dt} = k_2[A]^2 - k_2[A][A^*] - k_1[A]$

(d) $\dfrac{d[A^*]}{dt} = k_2[A][A^*] - k_1[A]$

(e) $\dfrac{d[A^*]}{dt} = k_1[A]^2 - k_{-1}[A][A^*]$