AL / systems

THE OPEN UNIVERSITY OF SRI LANKA
B. Sc. Degree Programme — Level 4
Assignment I (Test)— 2010/2011
(Part II/ 1-5 and Part III/1-4)
CHU 2124/CHE 4124 — Physical Chemistry I

$\left(1\frac{1}{2}\text{ hours}\right)$

29th Sept. 2010 4.00 p.m. — 5.30 p.m.

⌦ The paper has **two** parts, **Part A** and **Part B;**

- **Part A** consists of **eighteen (18)** MCQ questions (recommended time – 45 minutes)
- **Part B** consists of **03 (three)** Structured Questions for which answers must be written ONLY in the SPACE provided. (Recommended time: 45 minutes).
- Mobile phones are **NOT** allowed; **switch off** and leave them outside.

Please write your **Registration number, Name, and Address** clearly in the space provided on the reverse side of the MCQ answer sheet (see **last page)** attached to **Part B** of this question paper

Part – A

- Choose the correct answer to each of these questions and mark your answer with a cross **["X"]**.
- Any answer with more than **one** "**X**" marked will be considered as an *incorrect* answer.
- $\frac{1}{6}$ of the mark allotted for a correct answer will be deducted for incorrect answers
- Use a **PEN** (not a PENCIL) in answering.
- The use of a *non-programmable* electronic calculator is permitted.
- Mobile phones are **NOT** allowed; **switch off** and leave them outside.

Gas constant (R)	=	$8.314\ \text{J K}^{-1}\text{mol}^{-1}$
Avogadro constant (N_A)	=	$6.023\times10^{23}\ \text{mol}^{-1}$
Faraday constant (F)	=	$96{,}500\ \text{C mol}^{-1}$
Planck constant (h)	=	$6.63\times10^{-34}\ \text{J s}$
Velocity of light (c)	=	$3.0\times10^{8}\ \text{m s}^{-1}$
Standard atmospheric pressure	=	$10^{5}\ \text{Pa}\left(\text{N m}^{-2}\right)$
lnx	=	$2.303\ \text{Log}_{10}(\text{X})$

1. What are the molecular parameters that can be determined using molecular spectroscopy?

(i) Energy levels

(ii) Electrical polarizability

(iii) Bond strengths

(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. The intensity of a monochromatic beam of radiation of wave length 10 nm is 3.2×10^{-5} W m^{-2}. The number of photons crossing an area of 1.0 cm^2 (placed perpendicular to the direction of propagation of the beam) within 2 s is,

(a) 1.61×10^{8} (b) 3.22×10^{8} (c) 5.67×10^{8}
(d) 1.61×10^{12} (e) 3.22×10^{12}

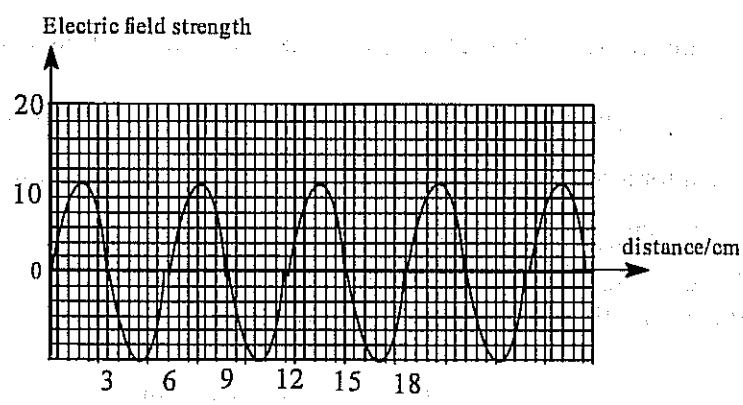
3. In a parallel beam of electromagnetic radiation, 2.25×10^{33} photons cross an area of 1.5 m^2 (placed perpendicular to the direction of propagation of the beam) in 2 s. What is the number density of photons in the beam?

(a) 2.50×10^{22} m^{-3} (b) 5.00×10^{22} m^{-3} (c) 2.50×10^{24} m^{-3}
(d) 5.00×10^{24} m^{-3} (e) 1.25×10^{24} m^{-3}

4. Which type of electromagnetic waves is used in changing the electronic configuration of a molecule (without altering its nuclear configuration)?

(a) Microwaves (b) Radio waves (c) Infrared waves
(d) Gamma rays (e) UV-Visible radiation

5. The graphical representation of a monochromatic electromagnetic wave is shown below.



Electric field strength is in V m^{-1}. What is the amplitude in (V m^{-1}) and the wave length (in cm) of the wave, respectively?

(a) 10, 6 (b) 20, 3 (c) 5, 1.5
(d) 20, 6 (e) 10, 3

6. What best represents the relationship between intensity, I, and amplitude (of the electric field strength), A, of an electromagnetic wave?

(a) $I = A$ (b) $I \propto A$ (c) $I \propto A^2$
(d) $I \propto 1/A^2$ (e) $I \propto 1/A$

7. Consider two chemical compounds X and Y which dissolves in a solvent Z forming a coloured solution. It is known that there are no interactions between X and Y molecules in solution. Y imparts the colour to the solution. The factors that determine the molar extinction coefficient of X in this solution are

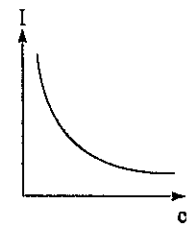
(i) The wave number of electromagnetic radiation

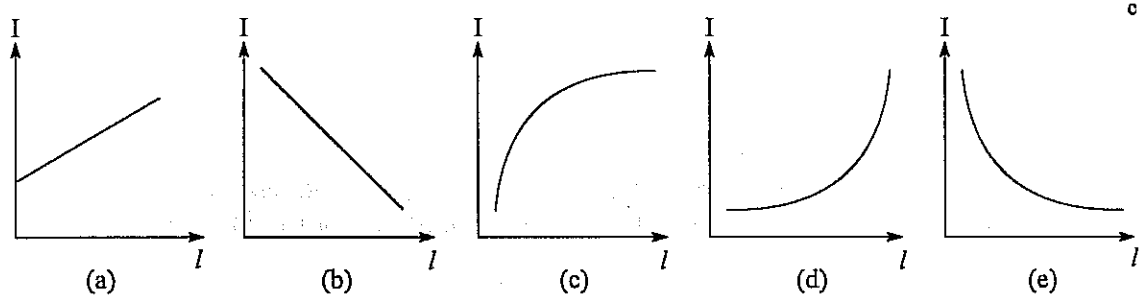
(ii) The colour of the solution.

(iii) The temperature of the solution.

(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.

8. A student kept a solution of a compound X in a cell of path length, l, in a single beam absorption spectrometer and measured the intensity, I, of the emergent beam of radiation at a particular frequency, ν. The molar concentration of X was c. It is known that only X absorbs radiation at frequency, ν. The I versus c plot, at constant path length, is shown in the figure to the right. Which of the following figures best represents the variation of I if l is varied at constant concentration.

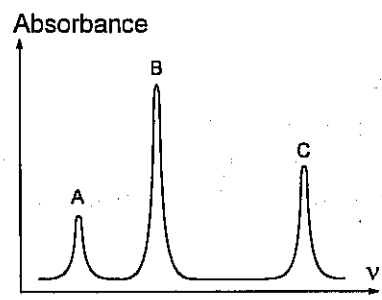




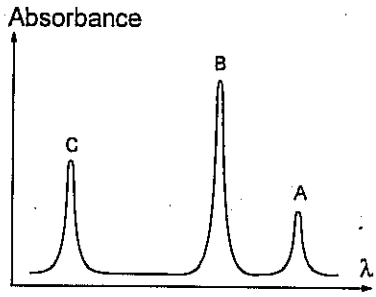
9. A chlorophyll solution at 25^0C is placed in a cell having a path length 2.0 cm. The measured absorbance at the 720 μm is 4.60. The molar absorption coefficient of chlorophyll is $52.2\ dm^3\ mol^{-1}\ cm^{-1}$ at 25^0C in the solution. What is the concentration of chlorophyll in the solution?

(a) $0.088\ mol\,dm^{-3}$ (b) $0.0044\ mol\,dm^{-3}$ (c) $0.044\ mol\,dm^{-3}$
(d) $0.88\ mol\,dm^{-3}$ (e) $0.0088\ mol\,dm^{-3}$

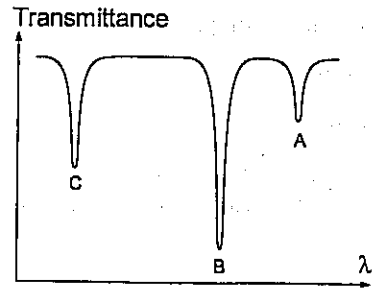
10. An absorption spectrum recorded by a student is shown below. The observed peaks are labelled as A, B and C.



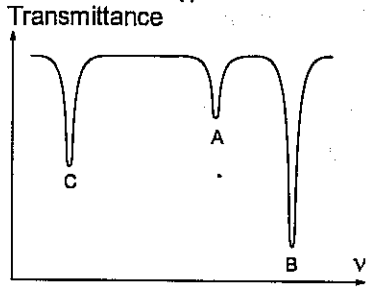
He proposed the following three alternatives for the same spectrum. [ν and λ are the frequency and wavelength of radiation, respectively]



(i)



(ii)



(iii)

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

11. As the detector, in a spectrometer, a

(i) thermocouple can be used in the microwave region.

(ii) photomultiplier tube can be used in UV-visible region.

(iii) crystal diode can be used in the microwave region.

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

12. The dipole moment of a single molecule

(i) may be a permanent feature of that molecule.

(ii) depends on the temperature of the sample where the molecule is in.

(iii) may appear only when the molecule is placed in an electric field.

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

13. Pick the molecules whose permanent dipole moment is zero.

(i) CCl_4 (ii) CS_2 (iii) Nitrobenzene (iv) p-chlorotoluene

(a) (i) and (ii) only. (b) (ii) and (iii) only. (c) (ii) and (iv) only.
(d) (iii) and (iv) only. (e) (i), (ii) and (iii) only.

14. The dipole moment of HX is 1.70×10^{-30} C m . What is the ionic character of the H-X bond whose length is 0.125 nm. $\left[e=1.602\times10^{-19}\ C\right]$

(a) 8.5% (b) 10.0% (c) 12.4% (d) 13.7% (e) 15.3%

15. Separation of a non-monochromatic light beam, into monochromatic components, can be achieved using

(i) diffraction grating.

(ii) a prism.

(iii) a combination of a prism and a diffraction grating.

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

16. A student merged two (parallel) beams, X and Y, of monochromatic radiation to obtain a single beam, of non-monochromatic radiation. The frequencies of the radiation in X and Y are 3.2×10^{10} Hz and 5.1×10^{10} Hz respectively. He found the photon number densities of X and the merged beam to be 1.5×10^{22} m^{-2} s^{-1} and 4.5×10^{22} m^{-2} s^{-1} respectively. What is the photon number density of beam Y?

(a) 1.5×10^{22} m^{-3} (b) 4.35×10^{22} m^{-3} (c) 3.00×10^{22} m^{-3}
(d) 4.35×10^{21} m^{-3} (e) 5.30×10^{22} m^{-3}

17. The absorbance of a sample of a solution depends on the

(i) path length of radiation through it.

(ii) cross sectional area of the cell used to place the sample in the spectrometer.

(iii) number of absorbing molecules per unit volume.

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

18. Compared to the spectrum recorded at high resolution, a spectrum of a molecule recorded at lower resolution, in the same range of frequencies, may appear to have

(i) a lesser (overall) number of peaks

(ii) broader peaks

(iii) lesser number of peaks at higher frequencies and larger number peaks at lower frequencies

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

Registration Number:----------; Signature (staff) ----------

Part B – 50% (answer **ONLY** in the space provided)

1 (a) (i) Write down the mathematical expression for Gibbs Phase rule using the standard symbols

(ii) What is meant by an

(α) intensive variable (β) extensive variable.

Name two examples in each case.

(25 marks)

(b) Identify the phases and independent components for the system involving the following equilibrium, the decomposition of Ammonium Chloride in a closed vessel.

$$NH_4Cl\ (solid) \rightleftharpoons NH_3\ (gas). + HCl\ (gas)$$

(15 marks)

2. (a) 90.00 cm^3 of water (density = 1.0 g cm^{-3}) is mixed with 25.50 cm^3 of pure ethanol (of relative molar mass 46 and density = 900 kg m^{-3}) forming a fully miscible system.

Calculate the mole fraction of ethanol in the mixture.

(25 marks)

(b) (i) A binary system consisting of **A** and **B** shows positive deviation from Raoults Law. Explain this statement.

(ii) What do you understand by the term "azeotrope"?

(iii) Sketch a fully labeled **boiling point vs composition phase diagram** for a binary system formed between two liquids, A and B that shows negative deviation from Raoults law.

(50 marks)

(c) Vapour pressures of pure A (relative molar mass = 100) and pure B (relative molar mass = 80) are, respectively, 9.0×10^4 Pa and 6.0×10^4 Pa at 60 °C. A and B are miscible at all compositions and form an ideal solution.

(i) Calculate the total vapour pressure and hence, the vapour composition corresponding to a mixture formed by mixing 50.0 g of A with 20.0 g of B at the above temperature (**Marks** will be awarded for writing down relevant **mathematical expressions**)

(25 marks)

3. (a) A solid S_A (M.Pt = 150 °C) and solid S_B (M.Pt = 80 °C) form a simple eutectic system with a eutectic composition at 45 °C. The mole fraction of solid S_A corresponding to the eutectic composition is 0.4.

(i) Sketch cooling curves corresponding to the eutectic composition and to a melt corresponding to an equimolar mixture of S_A and S_B;

(ii) Sketch a fully labelled phase diagram (highlighting the composition corresponding to the cooling curves mentioned above) for the above system.

(40 marks)

THE OPEN UNIVERSITY OF SRI LANKA
B. Sc. Degree Programme — Level 4
Assignment I (Test)— 2010/2011
(Part II/ 1-5 and Part III/1-4)
CHU 2124/CHE 4124 — Physical Chemistry I

29th Sept. 2010

Answer Guide for Part B (Structured Paper)

1 (a) (i) $F + P = C + 2$

(ii) (α) intensive variable:

That which is independent of the amount; eg: temperature, concentration

(β) extensive variable.

That which is dependent of the amount: volume, moles

(b) (Need to identify the phases and components in terms of the chemical species present)

$$NH_4Cl\ (solid) \rightleftharpoons NH_3\ (gas) + HCl\ (gas)$$

Two phases; NH_4Cl (solid) and the gaseous mixture of HCl and NH_3

Two components; any two of NH_4Cl (solid), NH_3 (gas) and HCl (gas)

2. (a) Number of moles of water = 90 x 1/18 = 5 moles

Density of ethanol = 900 kg m^{-3} = 900 x 10^3 x 10^{-6} g cm^{-3} = 0.9 g cm^{-3}

Mass of ethanol = 25.5 x 0.9 = 23 g

Number of moles of ethanol = 23/46 = 0.5

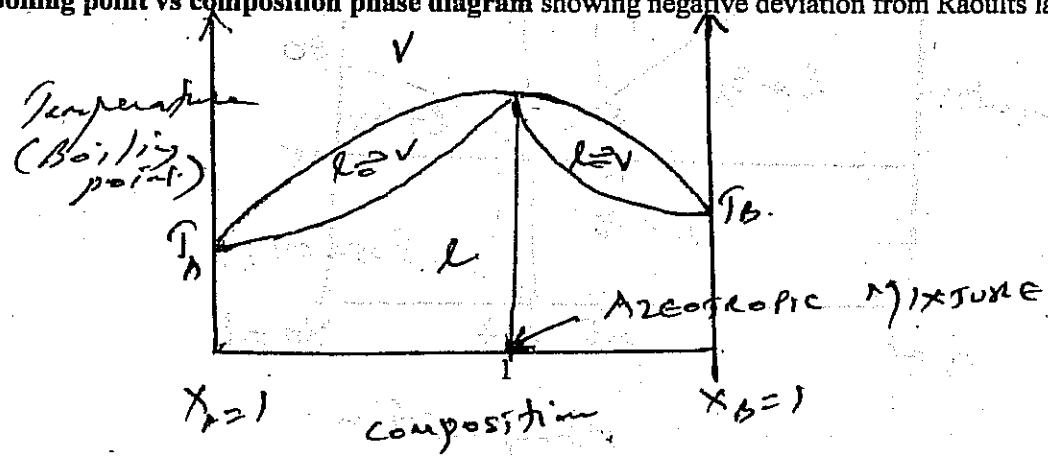
Mole fraction of ethanol = (0.5)/0.5 + 5 = 1/11

(b) (i) Postive deviation from Raoults occurs as a results of A – B < A- A and B-B (intermolecular forces); thus the vapour pressures deviate from the ideal values (is greater than) calculated in accordance with Raoults law

[Credit given for showing this graphically]

(ii) An azeotrope corresponds to a mixture with constant boiling point having ~~whose~~ vapour composition ~~is the~~ same as that of the liquid at the boiling point.

(iii) **Boiling point vs composition phase diagram** showing negative deviation from Raoults law.



(c) (i) Total vapour pressure, P_T = Sum of Partial Vapour pressures = $P_A + P_B$

$P_A = X_A P^o_A$; $P_B = X_B P^o_B$ (according to Raoults Law)

$n_A = 50/100 = 0.5$ (moles of A); $n_B = 20/80 = 0.25$ (moles of B)

$X_A = 0.5/(0.5+0.25) = 0.5/0.75 = 2/3$

Hence, $X_B = 1-2/3 = 1/3$

Therefore, $P_A = (2/3)\text{x } 9.0 \text{ x } 10^4 = 6 \text{ x } 10^4$ Pa; $P_B = (1/3)\text{x } 6.0 \text{ x } 10^4 = 2.0 \text{ x } 10^4$ Pa

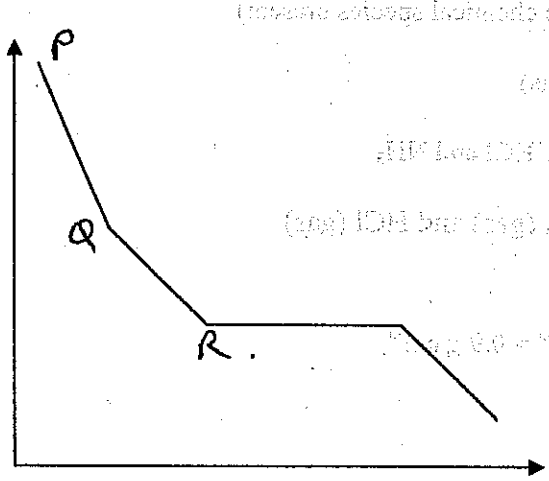
$P_T = 8.0 \text{ x } 10^4$ Pa

Also $P_A = X^v_A P_T$ and $P_B = X^v_B P_T$ where the mole fractions, X^v_A and X^v_B are the respective mole fractions in the vapour phase

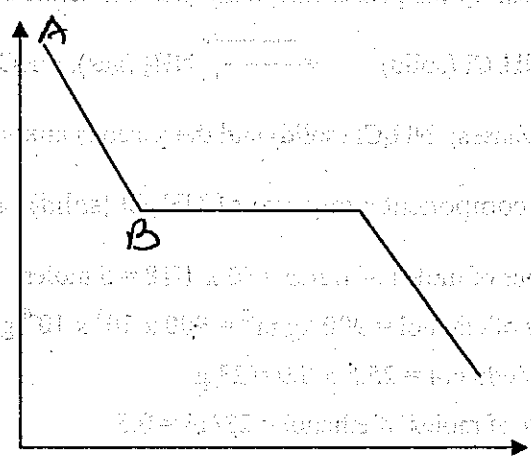
Therefore, $X^v_A = (6 \text{ x } 10^4)/8.0 \text{ x } 10^4 = ¾$; $X^v_B = 1/4$

(Any one of these values is sufficient in specifying the composition of the vapour phase)

3. (i) [Clear identification of the two cooling curves needed; one corresponding to the eutectic composition and the other corresponding to the equimolar composition]



Equimolar mixture of A and B



Eutectic composition

(ii) Phase diagram for the above system.