Comprehensive Exam, Engineering Chemistry, CHE F214, Karthik Chethan V., BITS-Pilani, Hyderabad Campus, Dec 17, 2022, Duration: 180 minutes, open book, Total Marks: 105. There is a total of seven questions. PS: 1) If any question contains the word JUSTIFY, then it means, reasoning is required. 2) keep answers short, you can use phrases it is sufficient and writing chemical structures is required wherever necessary. Do not simply cut and paste mindlessly from ppt or other sources and write it as answers. While illustrating plots, make sure the 'x' and 'y' axes are labelled properly with units, comprehensive and short answers are highly valued.

1. a) As discussed in class, consider ball and stick model for a atoms vibrating in a diatomic molecule and derive an expression for reduced mass **[5 M]**. b) For the same model and diatomic molecule, derive an expression for the atomic vibration frequency, frequency is proportional to $[k/mu]^{1/2}$ [Hint: i) the frequency is dependent on factors such as, bond stiffness (k) and reduced mass (mu), ii) use both Hookean law and Newtonian law expressions for force to begin with the derivation] **[9 M]**   **[Total = 14 M]**
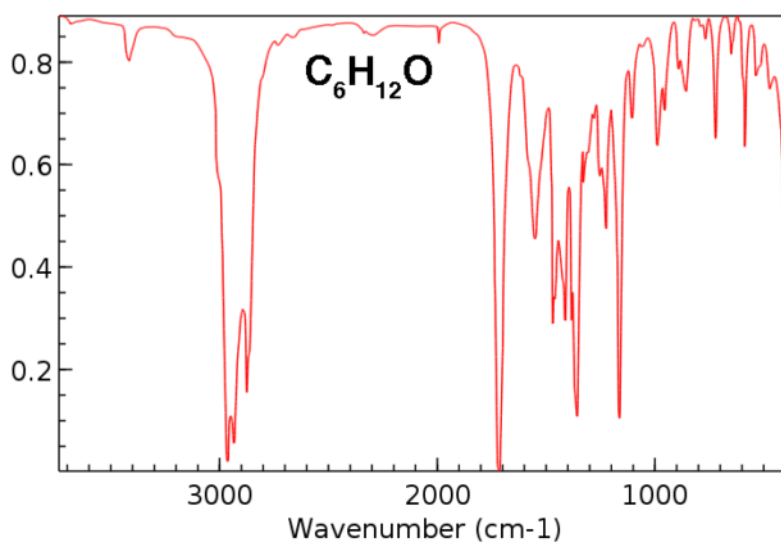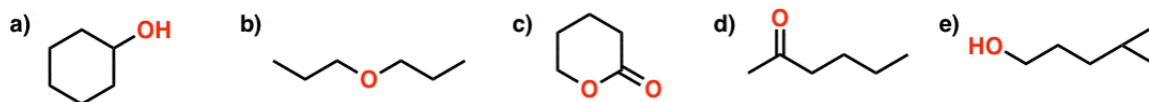
2. a) Consider the unknown molecule with molecular formula $C_5H_{10}O$. Which of these five molecules most likely corresponds to the IR spectrum below, justify your selection **[4 M]**. The IR spectrum is shown in transmittance (%) on y-axis and hence the absorbance peaks are facing downwards. [Hint: make sure the molecular formula matches with the structure provided and look for the most intense peaks in the spectrum and the functional group responsible for the same)

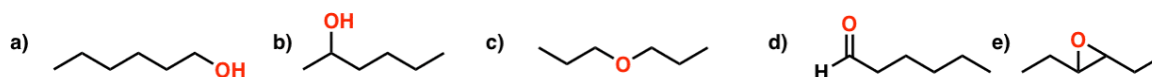**Which of these molecules best corresponds to the IR spectrum below?**
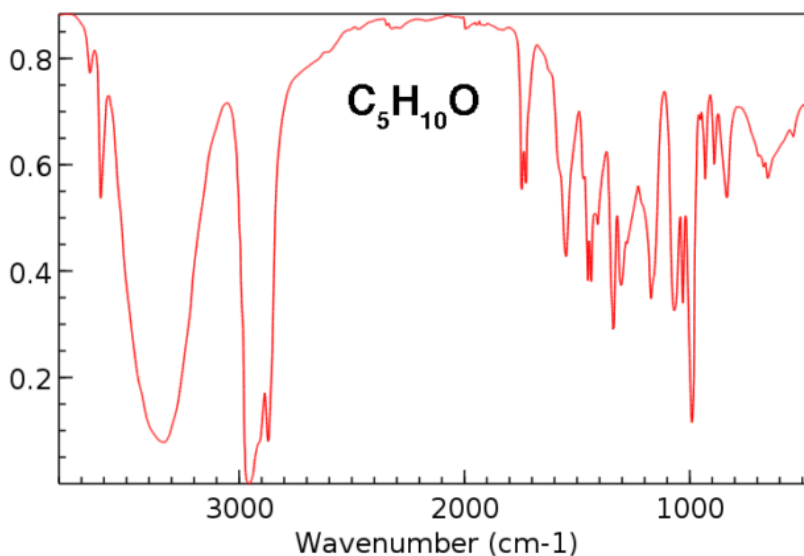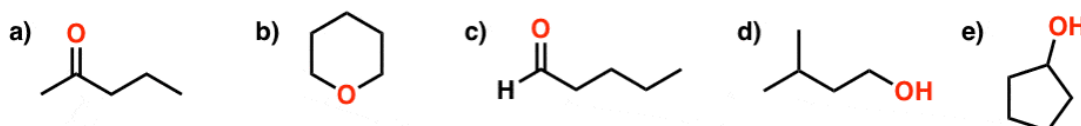
b) Consider the unknown molecule with molecular formula $C_6H_{12}O$. Which of these five molecules most likely corresponds to the IR spectrum below, justify your selection **[4 M]**.

Which of these molecules best corresponds to the IR spectrum below?

a)   b)   c)   d)   e)

$C_6H_{12}O$

Wavenumber (cm-1)

c) Consider the unknown molecule with molecular formula $C_6H_{14}O$. Which of these five molecules most likely corresponds to the IR spectrum below, justify your selection **[4 M]**.
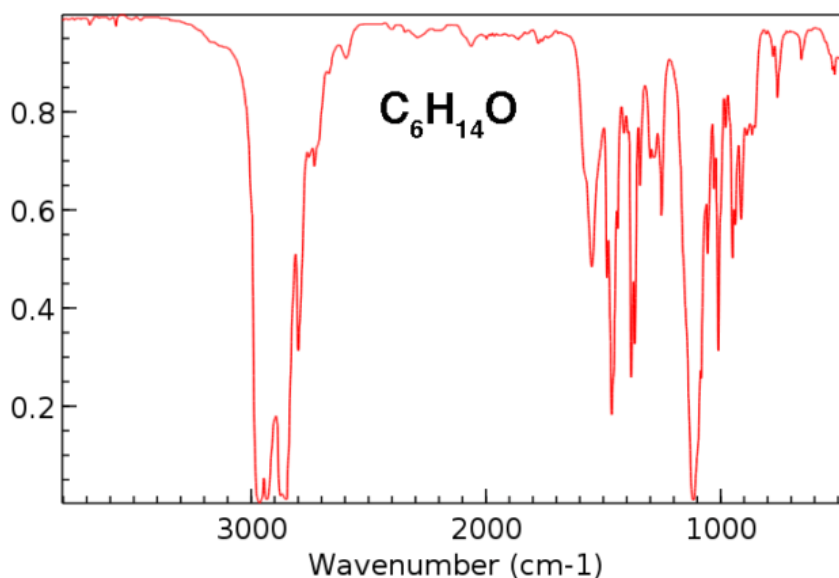
Which of these molecules best corresponds to the IR spectrum below with molecular formula $C_6H_{14}O$?

a)   b)   c)   d)   e)

d) Consider the unknown molecule with molecular formula $C_4H_8O_2$. Which of these five molecules most likely corresponds to the IR spectrum below, justify your selection **[4 M]**.
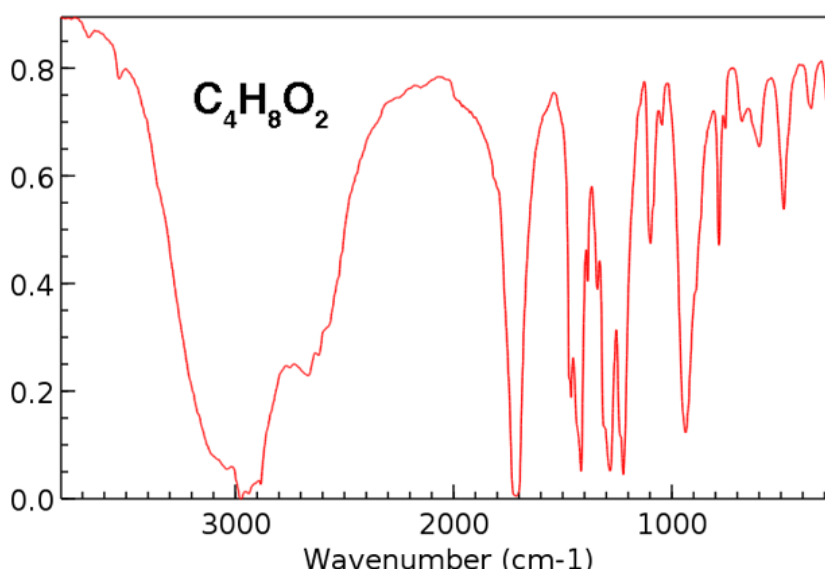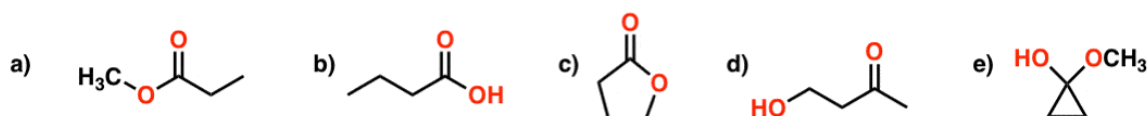
Which of these molecules best corresponds to the IR spectrum below?


[Total = 16 M]

3. a) The absorbance of a solution is 0.37. If the transmittance value of the blank sample (T_o) is 97%, what is the transmittance T of the solution? **[3 M]**.

b) Select the correct answer, in analytical chemistry,
UV spectrophotometer is mainly used :

i) To measure the concentration of a mixture of unknown compounds
ii) To measure the concentration of a known light absorbing compound.
iii) To identify compounds by their retention time.
iv) To determine the extinction coefficients of unknown compounds.
v) To study the relationships between absorption bands and structure. **[2 M]**

c) Select the correct answer, the diagram below contains information on radiation sources used in spectroscopy. Each range delimited by a horizontal line corresponds to:
a)The intensity of emission of the source
b)The λabsorption range of the source
c)The molar absorptivity of the source
d)The λemission range of the source
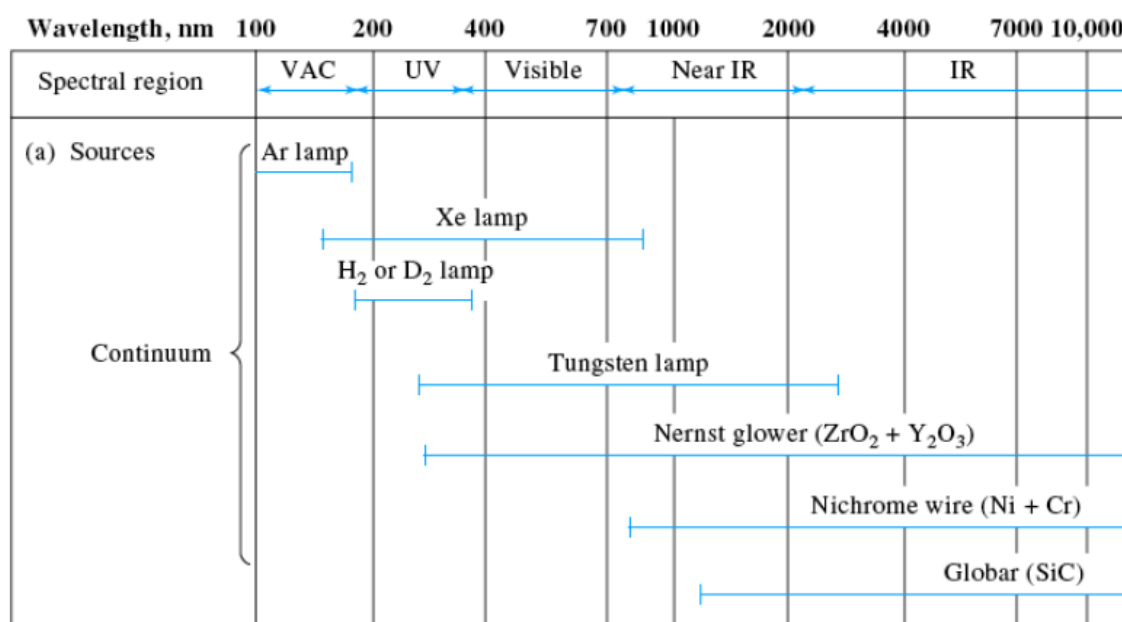
[2 M]

d) A UV calibration curve is prepared and ranges from 0 to 0.005 M of the analyte. The lab chemist measures the unknown, gets A = 0.125 and decides to extrapolate to calculate the concentration. What is the % error caused by this extrapolation?. **[3 M]**
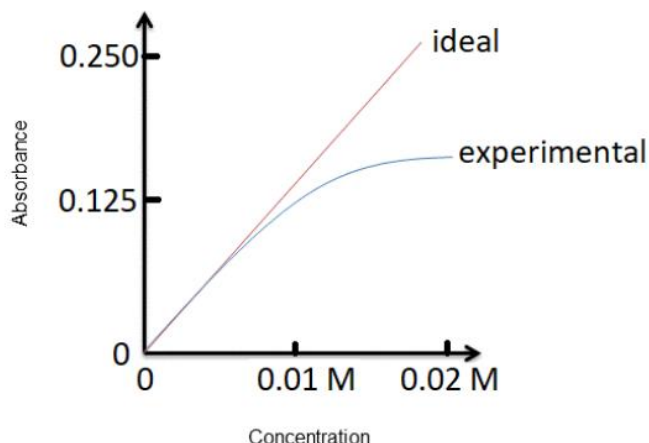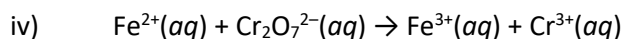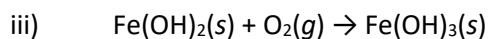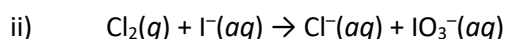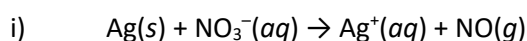
e) Name two possible causes of this deviation from Beer's law, use specific examples to make your point.   **[4 M]**
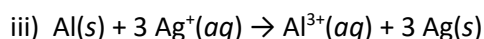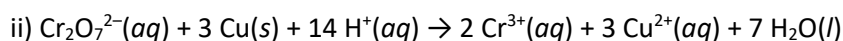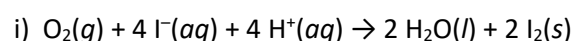
[Total = 14 M]

4. Consider a BET (multilayer) type of adsorption isotherm process for a certain gaseous adsorbate molecules on an adsorbent. Let the energy of adsorption for adsorption on the first layer be E_l and the energy of adsorption for succeeding layers be E_S. Illustrate the BET isotherm curves for the following two conditions on the same plot, label the plot neatly and comprehensively, i) $E_l \gg E_S$ and ii) E_l is slightly higher than E_S **[8 M]**

5. a) Balance the following equations (first write the oxidation and reduction half reactions and then balance, use water and H^+ as required in order to balance the equations and the final balanced equation should not contain e^-)   **[8 M]**

   i) $Ag(s) + NO_3^-(aq) \rightarrow Ag^+(aq) + NO(g)$

   ii) $Cl_2(g) + I^-(aq) \rightarrow Cl^-(aq) + IO_3^-(aq)$

   iii) $Fe(OH)_2(s) + O_2(g) \rightarrow Fe(OH)_3(s)$

   iv) $Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) \rightarrow Fe^{3+}(aq) + Cr^{3+}(aq)$

   b)   Determine the values of $E°_{cell}$ and $\Delta G°$ for the following reactions (write half-cell reactions and the overall reaction, prior to calculating $E°_{cell}$ and $\Delta G°$)   **[12 M]**

   i) $O_2(g) + 4\ I^-(aq) + 4\ H^+(aq) \rightarrow 2\ H_2O(l) + 2\ I_2(s)$

   ii) $Cr_2O_7^{2-}(aq) + 3\ Cu(s) + 14\ H^+(aq) \rightarrow 2\ Cr^{3+}(aq) + 3\ Cu^{2+}(aq) + 7\ H_2O(l)$

   iii) $Al(s) + 3\ Ag^+(aq) \rightarrow Al^{3+}(aq) + 3\ Ag(s)$

[Total = 20 M]

6. For each of these compounds, illustrate NMR spectra on separate plots and label the plots appropriately. The illustrations should contain i) the correct number of signals you expect in accordance with the different environments the protons are in, ii) the effect of shielding on the x-axis scale (chemical shift), and the effect of spin-spin coupling (splitting patterns).
[Total = 20 M]

a)

b)

c)

d)
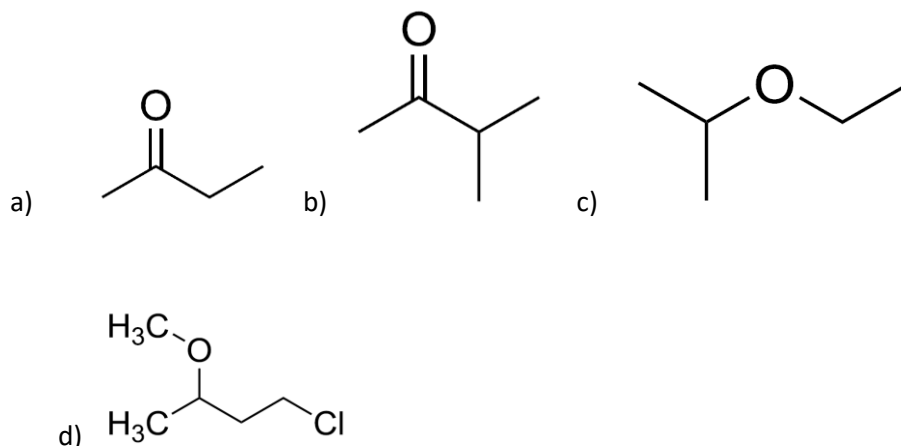
7. From the project activity videos answer the following questions briefly.
   a) In the "Rubber" activity video, few rubber products were mentioned and discussed. List five rubber products that are very significant for engineering applications **[4 M]**.
   b) In the "Entropy" activity video, differences between work and entropy was mentioned and discussed. That said, whenever one encounters a cold region or cold product or cold surface, briefly explain whether that region or product or surface is a result of high entropy or high work, justify **[2 M]**. Does high entropy mean high work or vice versa, justify **[2 M]**.
   c) In the "microfiber" activity video, adsorption was mentioned and discussed, that said, briefly explain why microfibers can effectively adsorb dust and facilitate in cleaning surfaces **[5 M]**.   **[Total = 13 M]**