

Analytical Chemistry II – MIDTERM EXAM II

- It is not allowed to put any additional items (e.g. cell phone, calculator) on the bench.
- Sign the exam paper, and sign the attendance list at the beginning of the exam.
- You have to hand in the exam paper before leaving the classroom.
- The exam consists of two parts (I and II).
- You can answer in English or Chinese language.
- Do not use pencil; use pen.
- If you cheat (e.g. use cell phone), you will get 0 points from this exam.

I. Choose the most accurate answer:

Circle the letter corresponding to your choice, or write the answer letter next to the question.
(maximum: $15 \times 4 = 60$ points)

1. What substrate gas is typically used to generate plasma state in inductively coupled plasma atomic emission spectroscopy?
 - air
 - oxygen
 - nitrous oxide
 - methane
 - argon
2. What is the drawback of echelle grating?
 - It cannot be used in atomic emission spectroscopy.
 - It has to be combined with another dispersing element to separate different orders of diffraction.
 - It cannot be combined with another dispersing element to separate different orders of diffraction.
 - It is not compatible with photomultiplier tube.
 - The wavelength bands from different orders of diffraction do not overlap.
3. What kind of analysis could you easily perform by glow-discharge optical emission spectroscopy?
 - determine the presence of copper in brass
 - determine the presence of iron in blood
 - determine the presence of caffeine in coffee
 - determine the presence of sodium in sea water
 - determine the presence of lead in river water
4. Which phototransducer is particularly suitable for portable photometers?
 - vacuum phototube
 - photomultiplier tube
 - LED
 - deuterium lamp
 - photovoltaic cell

5. What is the function of mechanical shutter in (spectro)photometers?
- a) to tune the signal corresponding to 50% transmittance
 - b) to remove radiation at the wavelengths corresponding to higher diffraction orders
 - c) to null dark response of the system
 - d) to select wavelength
 - e) to switch between sample cell and reference cell
6. Which light source is particularly suitable for infrared absorption spectroscopy?
- a) Globar
 - b) argon lamp
 - c) deuterium lamp
 - d) Ar lamp
 - e) HCL lamp
7. What is the typical effect of stray radiation on absorption measurements?
- a) At low real absorbance, measured absorbance is slightly higher than real absorbance.
 - b) At high real absorbance, measured absorbance is lower than real absorbance.
 - c) At high real absorbance, measured absorbance is much higher than real absorbance.
 - d) Auxochromic effect.
 - e) Measured absorbance is equal to real absorbance.
8. Why does β -carotene absorb blue light?
- a) due to the presence of conjugated double bonds
 - b) due to the presence of one aromatic ring
 - c) due to the presence of fused aromatic rings
 - d) due to blue shift
 - e) due to formation of complex with metal ions
9. By comparing UV absorption spectra of toluene and benzene, we can realize that the B band of toluene is at a different wavelength than the B band of benzene. How can we call this effect caused by the additional methyl group present in the molecule of toluene?
- a) hypsochromic shift
 - b) phase shift
 - c) red shift
 - d) blue shift
 - e) violet shift
10. Intersystem crossing
- a) is observed when an excited species emits radiation of the same frequency as that used to cause the excitation.
 - b) occurs when a molecule changes from a higher electronic state to an upper vibrational level of a lower electronic state in which the vibrational energy is great enough to rupture the bond.
 - c) occurs when radiation promotes a molecule directly to a state with sufficient vibrational energy for a bond to break.
 - d) is a radiationless process in which a molecule loses electronic energy while transferring that energy to the solvent or another solute.
 - e) is the process in which a molecule in one spin state changes to another spin state with nearly the same total energy.

11. In which molecule, fluorescence is significantly decreased due to intersystem crossing?
- a) quinine
 - b) C₆H₆
 - c) C₆H₅CH₃
 - d) C₆H₅Br
 - e) GFP
12. Which phototransducer would likely be used in spectrofluorometers designed for highly sensitive measurements?
- a) photovoltaic cell
 - b) photomultiplier tube
 - c) electron multiplier
 - d) phototube
 - e) LED
13. Which item is required for chemiluminescence detection?
- a) phototransducer
 - b) ion source
 - c) excitation monochromator
 - d) attenuator
 - e) laser
14. In IR spectroscopy, overtones are
- a) transitions, in which $\Delta\nu$ is 0
 - b) transitions, in which $\Delta\nu$ is 1
 - c) transitions, in which $\Delta\nu$ is $\pm 2, 3, \dots$
 - d) combination bands
 - e) rotational transitions
15. How many fundamental vibrational modes are observed in H₂O molecule?
- a) 0
 - b) 0.5
 - c) 2
 - d) 3
 - e) 12

II. Answer the following questions: (maximum: $4 \times 10 = 40$ points)

- Indicate the question letter before answering.
- Provide a complete, accurate, clear, high-quality answer to every part of each task.
- Adhere to the answer length limits. Up to 3 points may be deducted per question for exceeding the length limits.
- Handwriting must be clear.
- Schemes and graphs must be labeled.

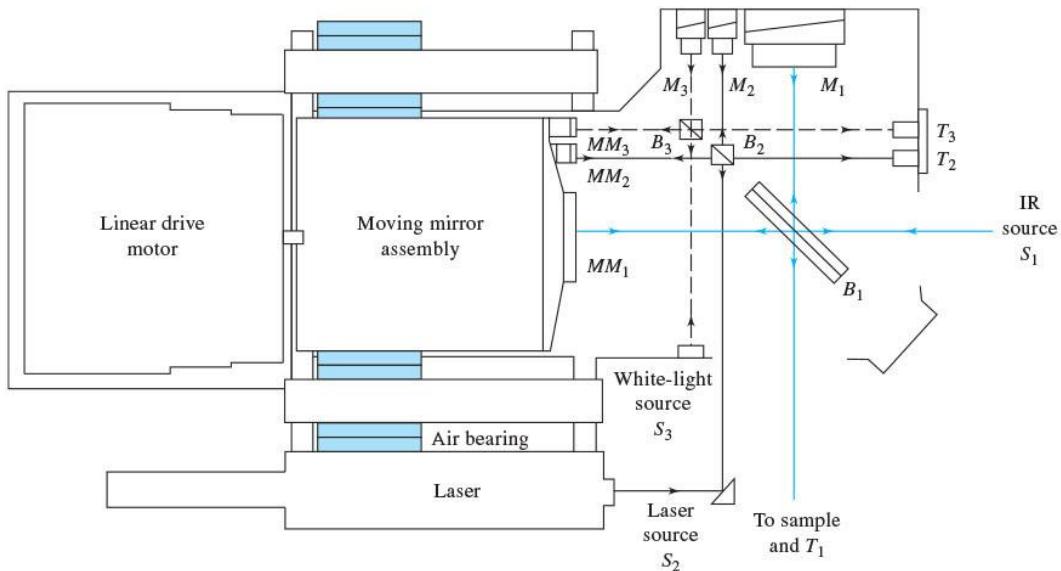
A. Draw scheme of double-beam-in-time spectrophotometer for UV-Vis range.

- *answer length limit: 1 figure with labels*

B. Define the following terms: (a) resonance fluorescence; (b) external conversion.

- *answer length limit: 100 words*

C. The drawing shows interferometer system of a modern FTIR instrument. Explain the principle of its operation. Mention the functions of the elements labeled as S_1 , S_2 , S_3 , M_1 , M_2 , M_3 , MM_1 , MM_2 , MM_3 , B_1 , B_2 , B_3 .



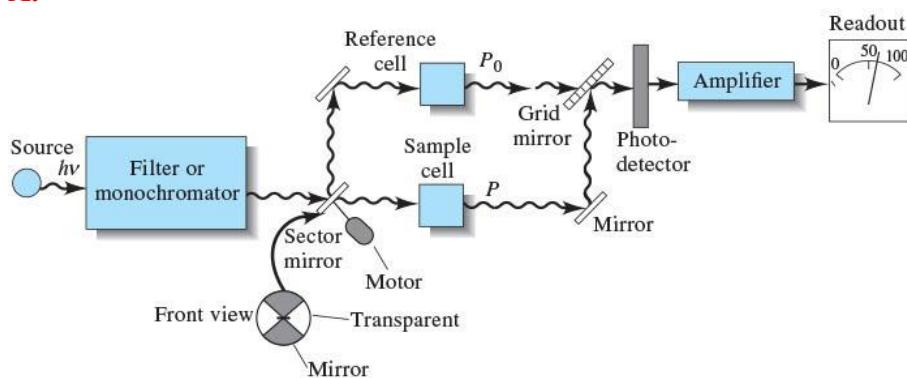
- *answer length limit: 350 words*

D. Draw block diagram of mass spectrometer. Indicate the main components of this instrument.

- *answer length limit: 1 figure with labels*

ANSWERS: (You can also use the reverse sides.)

A.



B.

- (a) Resonance fluorescence is observed when an excited species emits radiation of the same frequency as that used to cause the excitation.
(b) External conversion is a radiationless process in which a molecule loses electronic energy while transferring that energy to the solvent or another solute.

C.

This FTIR instrument takes advantage of three Michelson interferometers to record three interferograms. During its operation, the moving mirror assembly is moved. The beam from S_1 is split in B_1 , reflected from fixed mirror M_1 and movable mirror MM_1 , and the merged beams undergo interference between B_1 and sample. This way, IR interferogram is created, which can later be converted to IR spectrum. S_2 , B_2 , M_2 , and MM_2 are used to produce laser-fringe signal, to know the exact position of the moving mirror assembly. S_3 , B_3 , M_3 , and MM_3 are used to record white light interferogram, to know the position of the moving mirror assembly that corresponds to zero retardation.

S_1 – IR source used for recording IR interferogram/spectrum of the sample

S_2 – laser source used to record laser-fringe signal, to know the exact position of the moving mirror assembly

S_3 – white light source used to record white light interferogram, to know the position of the moving mirror assembly that corresponds to zero retardation

M_1 – fixed mirror used for recording IR interferogram/spectrum of the sample

M_2 – fixed mirror used to record laser-fringe signal, to know the exact position of the moving mirror assembly

M_3 – fixed mirror used to record white light interferogram, to know the position of the moving mirror assembly that corresponds to zero retardation

MM_1 – movable mirror used for recording IR interferogram/spectrum of the sample

MM_2 – movable mirror used to record laser-fringe signal, to know the exact position of the moving mirror assembly

MM_3 – movable mirror used to record white light interferogram, to know the position of the moving mirror assembly that corresponds to zero retardation

B_1 – beamsplitter used for recording IR interferogram/spectrum of the sample

B_2 – beamsplitter used to record laser-fringe signal, to know the exact position of the moving mirror assembly

B_3 – beamsplitter used to record white light interferogram, to know the position of the moving mirror assembly that corresponds to zero retardation

D.