# 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: 10 × 4 = 40 points)

1. If the transmittance has the value of 0.01, then what is the value of absorbance?
   a) 0.01
   b) 0.1
   c) 1
   d) 2
   e) 3

2. Which light source is particularly suitable for infrared absorption spectroscopy?
   a) argon lamp
   b) deuterium lamp
   c) Ar lamp
   d) Globar
   e) HCL lamp

3. Which phototransducer would likely be used in spectrofluorometers designed for highly sensitive measurements?
   a) photomultiplier tube
   b) photovoltaic cell
   c) phototube
   d) electron multiplier
   e) LED

4. What is the typical effect of stray radiation on absorption measurements?
   a) Auxochromic effect.
   b) Measured absorbance is equal to real absorbance.
   c) At low real absorbance, measured absorbance is slightly higher than real absorbance.
   d) At high real absorbance, measured absorbance is lower than real absorbance.
   e) At high real absorbance, measured absorbance is much higher than real absorbance.

5. Sulfur dioxide is a nonlinear molecule. How many vibrational modes will this compound have?
   a) 0
   b) 1
   c) 2
   d) 3
   e) 4

6. Isotopes contribute to mass spectral patterns of molecular ions. Which of the following elements has the highest abundance of the second most abundant naturally occurring isotope?
   a) hydrogen
   b) carbon
   c) nitrogen
   d) oxygen
   e) chlorine

7. Which of the following features is characteristic of electron ionization?
   a) molecular fragmentation
   b) operation at atmospheric pressure
   c) protonation of intact molecules
   d) desorption of molecules from liquid films
   e) suitability for analysis of nucleic acids

8. Multiple charging of proteins is most prominent in
   a) chemical ionization
   b) matrix-assisted laser desorption/ionization
   c) electron ionization
   d) inductively coupled plasma ionization
   e) electrospray ionization

9. What is the role of reflectron in time-of-flight mass spectrometer?
   a) to compensate for differences in molecular weight
   b) to compensate for kinetic energy spread of ions
   c) to adapt the mass analyzer for atomic mass spectrometry
   d) to make the mass analyzer compatible with MALDI source
   e) to reduce fragmentation of molecular ions

10. Which mass spectrometer can potentially provide the highest resolution?
   a) quadrupole
   b) FTICR
   c) ion trap
   d) TOF
   e) magnetic sector

**II. Answer the following questions:** (maximum: 6 × 10 = 60 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.** Describe the differences between filters and monochromators as wavelength selectors. List any particular advantages possessed by one over the other.
*- answer length limit: 100 words*

**B.** Why does a deuterium lamp produce a continuum rather than a line spectrum in the UV?
*- answer length limit: 120 words*

**C.** Why is spectrofluorometry potentially more sensitive than spectrophotometry?
*- answer length limit: 100 words*

**D.** Draw scheme of mass spectrometer. Indicate the main components.
*- answer length limit: 1 figure with labels*

**E.** Explain the operation of time-of-flight mass analyzer, and draw scheme of this mass analyzer.
*- answer length limit: 100 words, 1 figure with labels*

**F.** Explain the operation of matrix-assisted laser desorption/ionization source, and draw scheme of this source.
*- answer length limit: 100 words, 1 figure with labels*

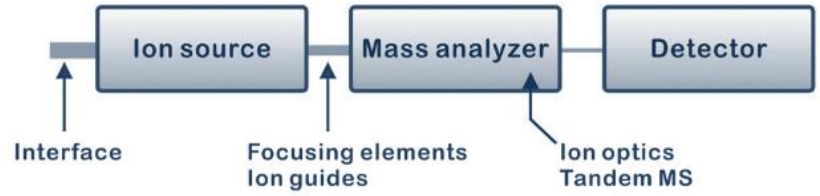
**ANSWERS:** (You can also use the reverse sides.)

**A.**
Filters provide low resolution wavelength selection often suitable for quantitative work, but not for qualitative analysis or structural studies. Monochromators produce high resolution (narrow bandwidths) for both qualitative and quantitative work.

**B.**
In a deuterium lamp, the lamp energy from the power source produces an excited deuterium molecule that dissociates into two atoms in the ground state and a photon of radiation. As the excited deuterium relaxes, its quantized energy is distributed between the energy of the photon and the energies of the two atoms. The latter can vary from nearly zero to the energy of the excited molecule. Therefore, the energy of the radiation, which is the difference between the quantized energy of the excited molecule and the kinetic energies of the atoms, can also vary continuously over the same range. Consequently, the emission spectrum is a spectral continuum.

**C.**
For spectrofluorometry, the analytical signal $F$ is proportional to the source intensity $P_0$ and the transducer sensitivity. In spectrophotometry, the absorbance $A$ is proportional to the ratio of $P_0$ to $P$. Increasing $P_0$ or the transducer sensitivity to $P_0$ produces a corresponding increase in $P$ or the sensitivity to $P$. Thus, the ratio does not change. As a result, the sensitivity of fluorescence can be increased by increasing $P_0$ or transducer sensitivity, but that of absorbance does not change.

**D.**

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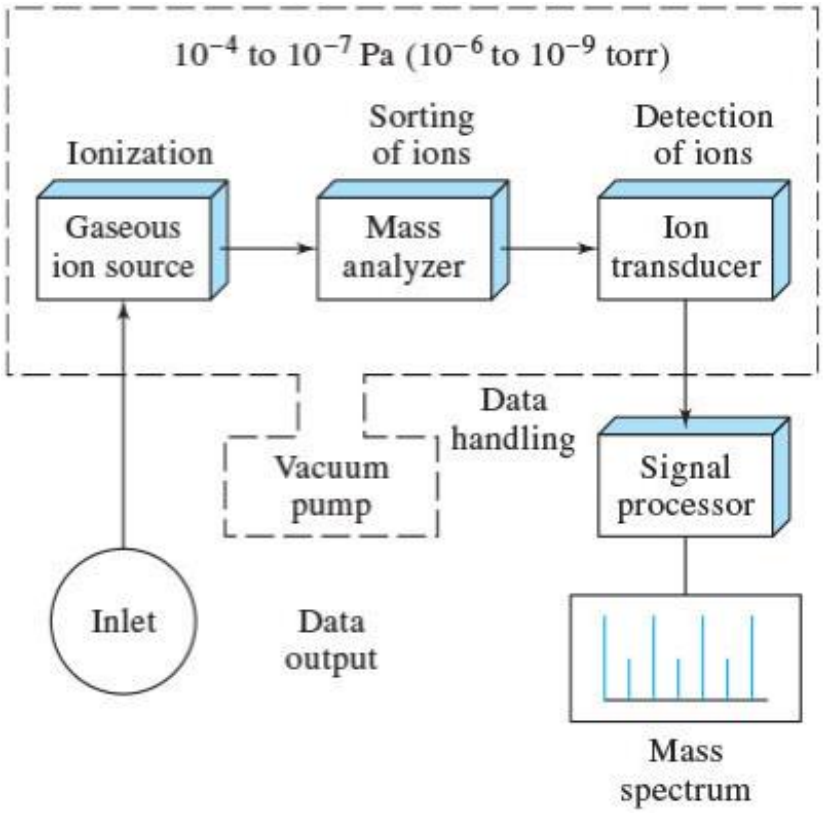
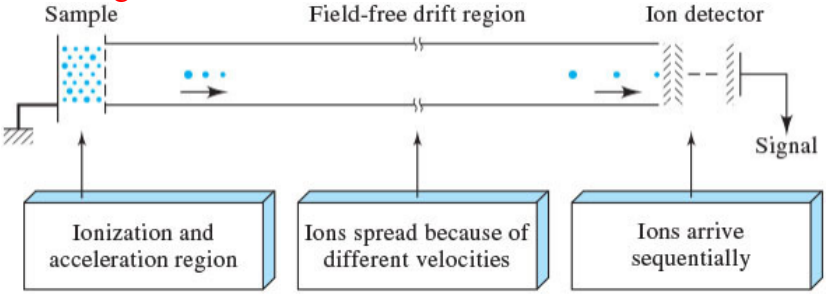


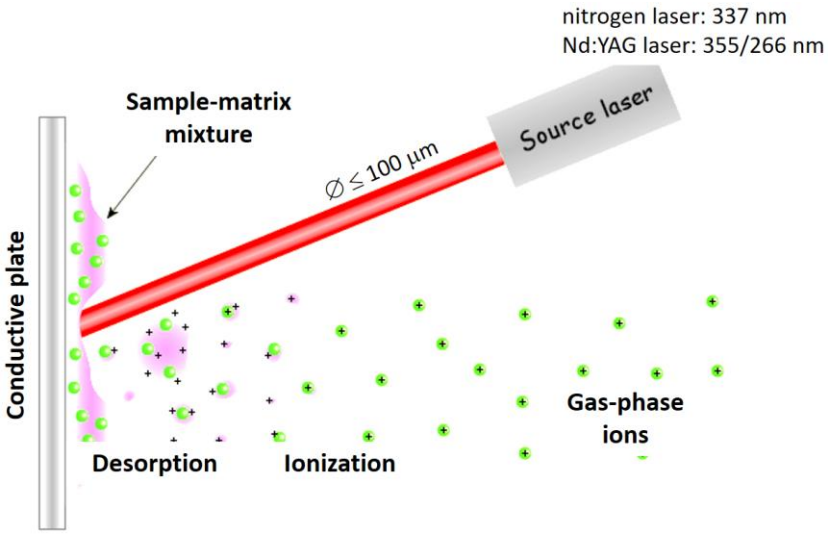

**E.**

- The time required for ions to travel from an ion source to a detector is measured.
- The ions receive approximately the same kinetic energy during ionization and acceleration.
- The accelerated ions pass to a field-free drift tube (ca. 1-2 m).
- The lighter ions arrive at the detector earlier than the heavier ions.




**F.**

Sample is mixed with a chemical matrix, and the mixture is deposited on a conductive plate. The mixture solvent is evaporated. The plate is inserted to the ion source compartment. The dry sample/matrix deposit is irradiated with laser beam to produce gas-phase ions.


nitrogen laser: 337 nm
Nd:YAG laser: 355/266 nm
Sample-matrix mixture
Source laser
∅ ≤ 100 μm
Conductive plate
Gas-phase ions
Desorption
Ionization