Analytical Chemistry II – MIDTERM EXAM I

- **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 be punished.**

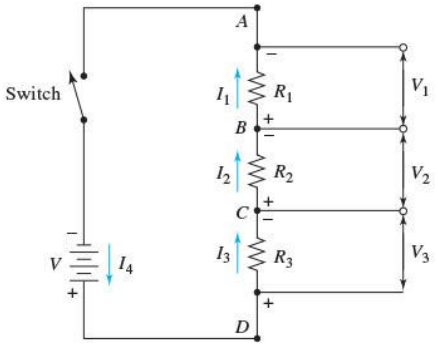
I. Choose the most accurate answer:

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

1. What characteristic property is measured using conductometry?
   a) thermal characteristics
   b) electrical resistance
   c) power of transmitted light
   d) mass
   e) capacitance

2. Which figure of merit can be used to characterize precision of an analytical method?
   a) mean
   b) average
   c) relative standard deviation
   d) coefficient of selectivity
   e) limit of quantification

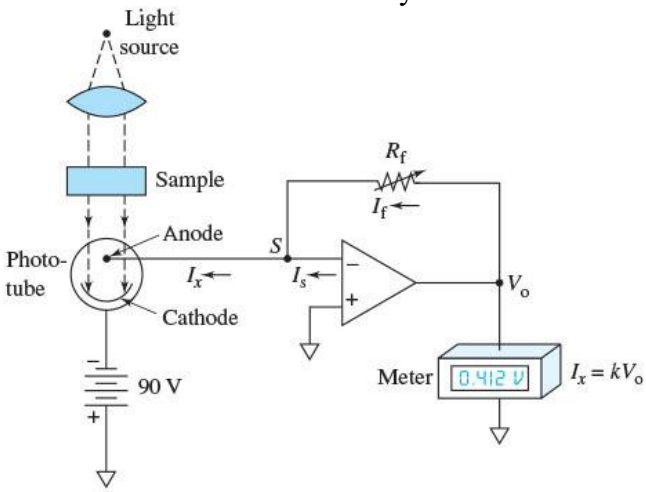
3. Which formula relates V_1 with V, R_1, R_2, and R_3 in the circuit below?



   a) $V_1 = V\left(\frac{R_2+R_3}{R_1+R_2+R_3}\right)$
   b) $V_1 = V(R_1 + R_2 + R_3)$
   c) $V_1 = V\left(\frac{R_1+R_2+R_3}{R_1}\right)$
   d) $V_1 = V\left(\frac{R_1}{R_1+R_2+R_3}\right)$
   e) $V_1 = V\left(\frac{R_1+R_2+R_3}{R_2+R_3}\right)$

4. Loading error in voltage measurements
   a) becomes smaller as the meter resistance becomes larger relative to the source resistance.
   b) becomes larger as the meter resistance becomes larger relative to the source resistance.
   c) does not depend on the meter resistance and source resistance.
   d) is particularly high when using op amps for voltage measurements.
   e) is always so small that it can be neglected.

5. What kind of circuit can you see in this scheme of an analytical instrument?



   a) comparator
   b) oscilloscope
   c) high-pass filter
   d) current follower
   e) non-inverting voltage amplifier

6. Convert the binary number '00101' to decimal number.
   a) 3
   b) 5
   c) 7
   d) 11
   e) 111

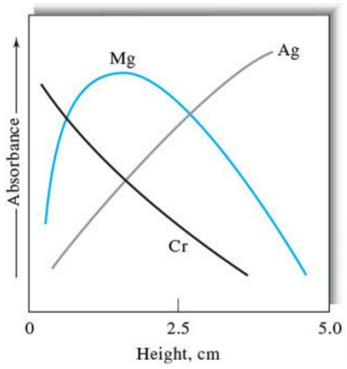
7. ADCs digitize at different rates. What conversion rate is required if a chromatographic peak is to be sampled and digitized 25 times between the first positive deflection from the baseline until the peak returns to the baseline? The total baseline-to-baseline time is (i) 20 s and (ii) 1 s.
   a) (i) 1.25 Hz, (ii) 25 Hz
   b) (i) 500 Hz, (ii) 25 Hz
   c) (i) 25 Hz, (ii) 25 Hz
   d) (i) 20 Hz, (ii) 1 Hz
   e) (i) 0.8 Hz, (ii) 0.04 Hz

8. Which wavelength range of electromagnetic radiation corresponds to vacuum ultraviolet light?
   a) 0.6-10 m
   b) 0.78-300 μm
   c) 400-780 nm
   d) 180-400 nm
   e) 10-180 nm

9. What is the definition of absorbance (A)? (P_0 – power of incident light, P – power of transmitted light)
   a) $A = \frac{P_0}{P}$
   b) $A = \frac{P}{P_0}$
   c) $A = \log\frac{P}{P_0}$
   d) $A = \log\frac{P_0}{P}$
   e) $A = P - P_0$

10. What is the sequence of events in flame atomic absorption spectroscopic analysis of liquid samples?
   a) excitation→dissociation→volatilization→desolvation→nebulization
   b) nebulization→dissociation→excitation→desolvation→volatilization
   c) nebulization→desolvation→volatilization→dissociation→excitation
   d) nebulization→excitation→desolvation→volatilization→dissociation
   e) dissociation→volatilization→nebulization→desolvation→excitation

11. The graph shows absorbances of three elements in relation to measurement height in flame atomization atomic absorption spectroscopy. Why does the Cr absorbance decrease with increasing measurement height?



   a) because of increasing dissociation of Cr compounds
   b) because Cr forms very stable oxides
   c) because Cr does not easily form oxides
   d) because Cr shows high atomization efficiency
   e) because Cr easily reacts with hydrogen in the flame

12. Which element can readily be analyzed by cold-vapor atomization atomic absorption spectroscopy?
   a) lead
   b) mercury
   c) potassium
   d) carbon
   e) copper

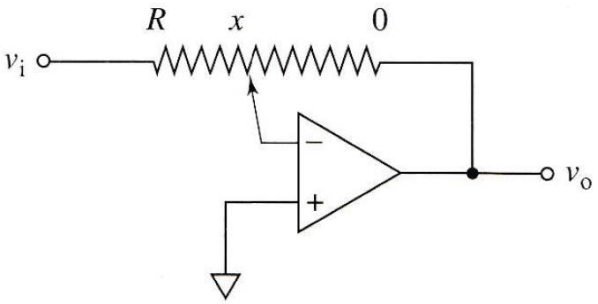
13. Which of the following light sources provides line spectrum?
   a) the Sun
   b) deuterium lamp
   c) tungsten lamp
   d) xenon arc lamp
   e) EDL lamp

14. What is the advantage of double-beam atomic absorption spectrophotometer as compared with single-beam atomic absorption spectrophotometer?
   a) It corrects the signal for fluctuations in lamp intensity.
   b) It corrects the signal for interferences related to combustion products that absorb or scatter light.
   c) It corrects the signal for fluctuations in flame temperature.
   d) It corrects the signal for solute volatilization interferences.
   e) It corrects the signal for chemical interferences.

15. Addition of potassium to sample can improve sensitivity in analysis of strontium by flame atomic absorption spectrometry. In this case, potassium is:
    a) protective agent
    b) releasing agent
    c) radiation buffer
    d) ionization suppressor
    e) solute volatilization interferent

II. Answer the following questions: (maximum: 4 × 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. In the following circuit, R is a variable resistor. Derive an equation that describes v_o as a function of v_i and the position x of the movable contact of the voltage divider. Perform the derivation such that x is zero if there is zero resistance in the feedback loop.
- answer length limit: 5 lines of text (including equations)



B. What types of noise are (i) frequency-dependent and (ii) frequency-independent?
- answer length limit: 20 words (2 items per category)

C. List the types of (i) spectral interferences and (ii) chemical interferences in atomic absorption spectroscopy.
- answer length limit: 50 words (3 items per category)

D. Describe operation of inductively coupled plasma (ICP) source for atomic emission spectroscopy. Illustrate this description with a drawing.
- answer length limit: 100 words, 1 figure with labels

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

A.

$$v_o = -ix \quad \text{and } v_+ = v_- = 0$$

$$v_i = i(R - x)$$

$$\frac{v_o}{v_i} = \frac{-ix}{i(R-x)} = -\frac{x}{R-x}$$

$$v_o = -\left(\frac{x}{R-x}\right)v_i$$

B.

Frequency-dependent noise sources: flicker and environmental noise.
Frequency-independent sources: thermal and shot noise.

C.

Spectral interferences:

- Two overlapping lines (rare)
- Combustion products that absorb or scatter light
- An interfering species present in the sample

Chemical interferences:

- Formation of compounds of low volatility
- Dissociation equilibria
- Ionization equilibria

D.

- Plasma is an electrically conducting gaseous mixture containing cations and electrons.
- Plasmas achieve high temperatures (even 10,000 K).
- The inductively coupled plasma (ICP) torch consists of concentric quartz tubes.
- Argon is supplied at 5-20 L min^{-1}.
- Induction coil is powered by radio-frequency (RF) generator (0.5-2 kW, MHz range).
- Ions and electrons interact in the fluctuating magnetic field.
- Heat is produced due to the movements of ions and electrons to induced by the magnetic field.
- Tangential flow of argon cools the quartz elements and focuses plasma radially.