Student's name: _____ Student's ID No.: _____

Analytical Chemistry II – MIDTERM EXAM I

- **It is not allowed to put any additional items (*e.g.* cell phone) 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, 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: 20 × 4 = 80 points)

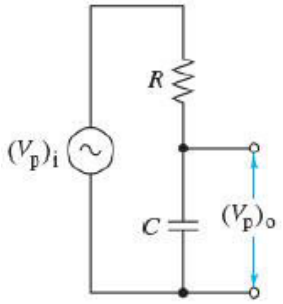
1. What characteristic property is measured using conductometry?
   a) mass
   b) capacitance
   c) power of transmitted light
   d) electrical resistance
   e) thermal characteristics

2. Convert the binary number '00111' to decimal number.
   a) 3
   b) 5
   c) 7
   d) 11
   e) 111

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

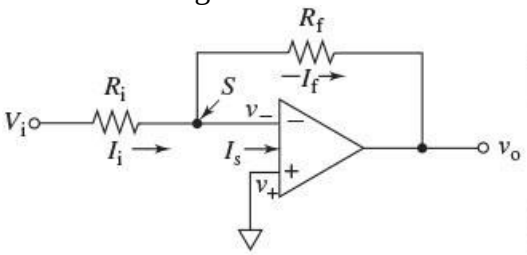
4. Loading error in voltage measurements
   a) becomes smaller as the meter resistance becomes larger relative to the source resistance.
   b) becomes larger as the meter resistance becomes larger relative to the source resistance.
   c) does not depend on the meter resistance and source resistance.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

5. What is the name/function of this electronic circuit?



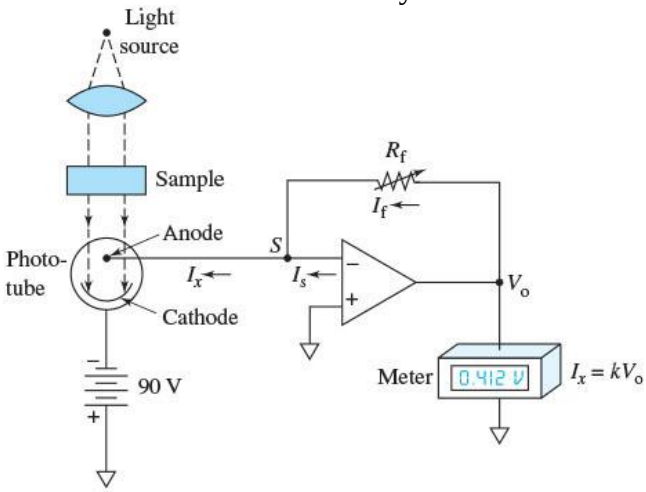
a) operational amplifier
b) transistor
c) low-pass filter
d) high-pass filter
e) rectifier

6. What is the output voltage (v_o) in the following circuit?



a) $v_o = -V_i \frac{R_f}{R_i}$
b) $v_o = -V_i \frac{R_i}{R_f}$
c) $v_o = -V_i \frac{R_f}{R_f+R_i}$
d) $v_o = -V_i \frac{R_i}{R_f+R_i}$
e) $v_o = -V_i$

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



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

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

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

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

11. Which technique is suitable for trace analysis of heavy metals in volume-limited samples (<5 μL)?
   a) concentric tube nebulizer inductively coupled plasma atomic emission spectrometry
   b) concentric tube nebulizer flame atomic absorption spectrometry
   c) cross-flow nebulizer flame atomic absorption spectrometry
   d) fritted disk nebulizer flame atomic absorption spectrometry
   e) electrothermal atomization atomic absorption spectrometry

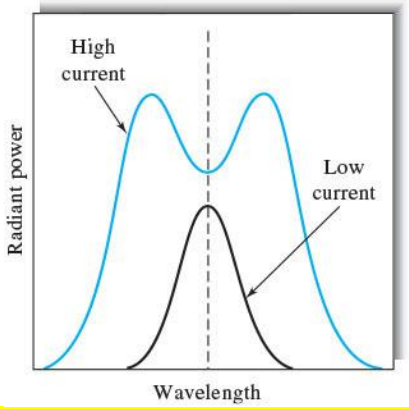
12. Which element can readily be analyzed by cold-vapor atomization atomic absorption spectrometry?
   a) sodium
   b) cadmium
   c) silicon
   d) mercury
   e) uranium

13. Which of the following light sources privides line spectrum?
   a) the Sun
   b) deuterium lamp
   c) HCL lamp
   d) tungsten lamp
   e) xenon arc 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 fluctuations in flame temperature.
   c) It corrects the signal for solute volatilization interferences.
   d) It corrects the signal for interferences related to combustion products that absorb or scatter light.
   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) releasing agent
    b) protective agent
    c) ionization suppressor
    d) radiation buffer
    e) solute volatilization interferent

16. The graph shows emission profiles for HCL lamp at different currents. What is the reason of the local minimum at the observation wavelength in high-current operation?



    a) absorption of emitted radiation by unexcited atoms in the lamp
    b) absorption of emitted radiation by argon ions in the lamp
    c) Zeeman effect
    d) isotopic effect
    e) contamination

17. Which gas is typically used to generate inductively coupled plasma?
    a) hydrogen
    b) methane
    c) argon
    d) oxygen
    e) nitrous oxide

18. In inductively coupled plasma source, plasma state is generated with the aid of:
    a) DC electric field
    b) permanent magnet
    c) microwave transducer
    d) RF magnetic field
    e) laser light

19. The zone in inductively coupled plasma source used for atomic emission spectroscopic measurements has a temperature of:
    a) ~ 300 K
    b) ~ 600 K
    c) ~ 1000 K
    d) ~ 6000 K
    e) ~ 120000 K

20. In laser-induced breakdown spectroscopy:
    a) a laser is used to ablate sample, create plasma, and excite atoms
    b) a laser is used to ablate sample, create plasma, and excite molecules
    c) a laser is used to generate inductively coupled plasma
    d) a laser is used to nebulize liquid sample for atomic absorption spectrometry
    e) absorbance of analyte is measured using laser light

II. Answer the following questions: (maximum: 4 × 5 = 20 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 5 points may be deducted per question for exceeding the length limits.
- Handwriting must be clear.
- Schemes and graphs must be labeled.

A. Define the term "transducer". Give examples of two transducers used in analytical instruments.
- *answer length limit: 50 words*

B. Explain the principle of hydride generation and atomization system. Illustrate this explanation with a scheme of the required apparatus.
- *answer length limit: 100 words, 1 figure with labels*

C. Draw schematic of multichannel spectrometer (Paschen-Runge design) for inductively coupled plasma atomic emission spectrometry.
- *answer length limit: 1 figure with labels*

D. Explain the operational principle of photomultiplier tube. Illustrate this explanation with a scheme of this device.
- *answer length limit: 150 words, 1 figure with labels*

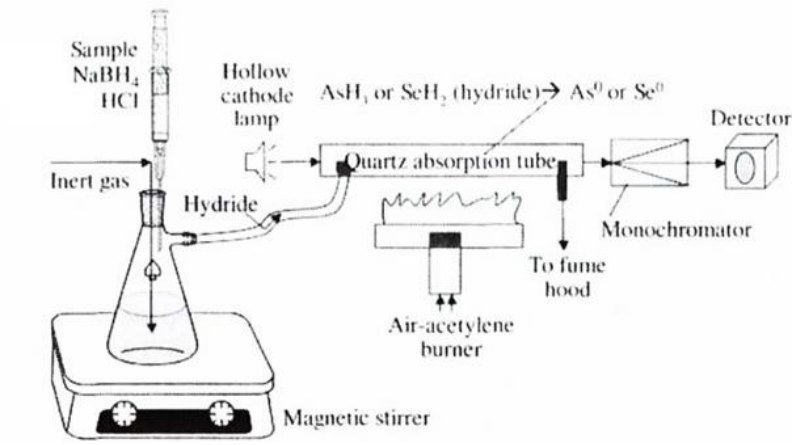
ANSWERS:

A.
- A transducer is a device that converts chemical or physical information into an electrical signal or the reverse. The most common input transducers convert chemical or physical information into a current, voltage, or charge.
- Examples: photodiode, photomultiplier tube, electrodes, electron multiplier.

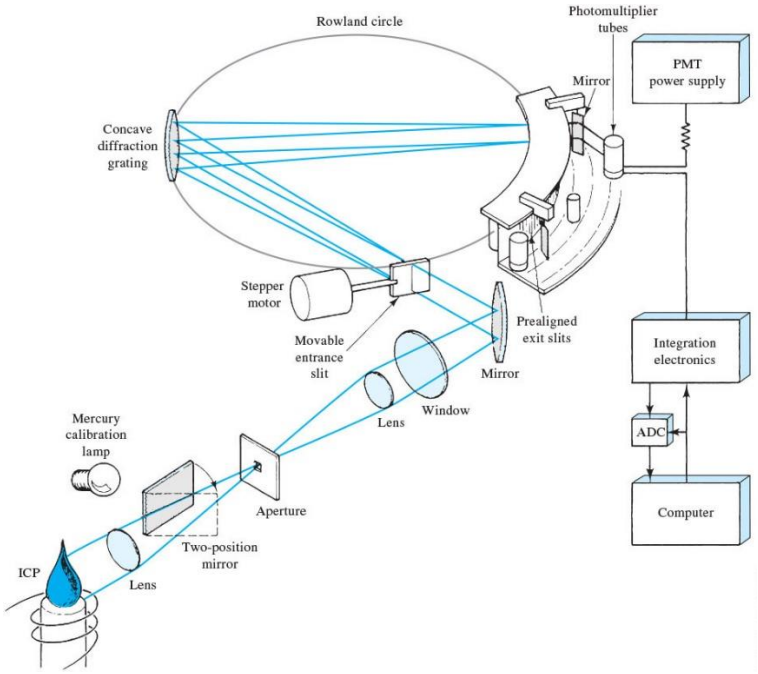
B.
- Hydride generation is applicable to analysis of As, Sb, Sn, Se, Bi, and Pb.
- Volatile hydrides are generated by mixing aqueous solution of the sample, acid, and aqueous solution of sodium borohydride in a glass vessel.
- For example:

$$3BH_4^-(aq) + 3H^+(aq) + 4H_3AsO_3(aq) \longrightarrow 3H_3BO_3(aq) + 4AsH_3(g) + 3H_2O(l)$$

- Hydrides are heated in a quartz tube to atomize the analyzed element.

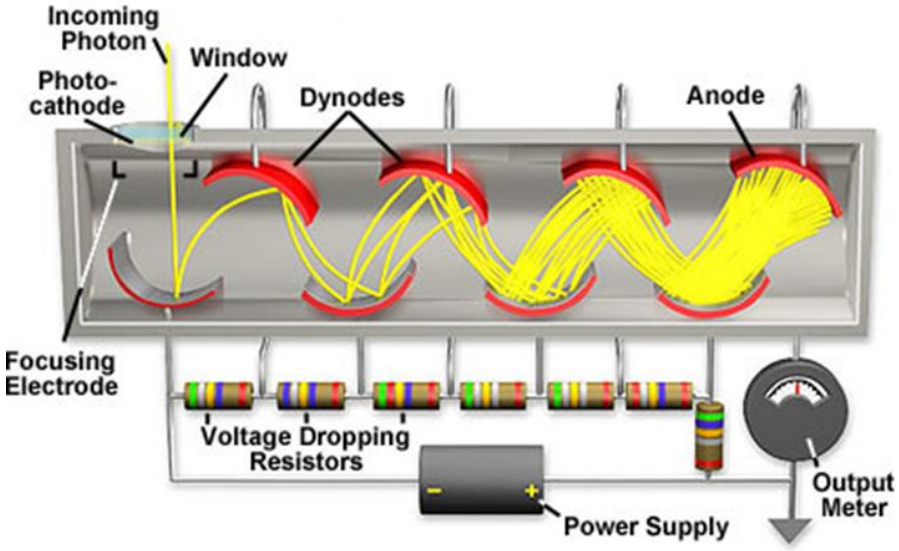


C.



D.

- Photons impinge on the surface of photocathode ejecting electrons in the course of photoelectric effect.
- The electrons are accelerated in the vacuum compartment toward the first dynode due to a potential difference between the photocathode and the first dynode.
- Secondary electrons are emitted from the dynode surface.
- The secondary electrons are accelerated to the second dynode, and they eject more electrons. The process is repeated at consecutive dynodes.
- The consecutive dynodes are supplied with increasing potentials to direct the electron beam.
- A large number of secondary electrons hits the last electrode (anode).
- The incoming electrons produce an electric current in the accompanying detection circuit.
- The current is proportional to radiant power of the light beam supplied to the photocathode.


Incoming Photon
Window
Photo-cathode
Dynodes
Anode
Focusing Electrode
Voltage Dropping Resistors
Output Meter
Power Supply