

Please show your work for all questions requiring calculations. No work, no credit!

- 1) Use a provided ruler to measure the length of the shoeprint below in centimeters. Report your measurement to the correct number of digits with units. (3)



The length is reported to two decimal places with units. 4.12 cm

- 2) Diazodinitrophenol (DDNP) is an explosive. What is the mass in pounds (lb) of a 4.25 kg sample of DDNP collected from a crime scene? Report your answer with three digits and units. (4)

1 lb = 453.6 grams and 1 kg = 1000g.

$$4.25 \text{ kg} * \frac{1000\text{g}}{1 \text{ g}} * \frac{1 \text{ lb}}{453.6 \text{ g}} = 9.37 \text{ lb}$$

- 3) Are the following compounds from CH 114 labs so far this term organic or inorganic? (3)

a) $\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$ (caffeine) **organic (contains carbon)**

b) $\text{C}_9\text{H}_8\text{O}_4$ (aspirin) **organic (contains carbon)**

c) FeCl_3 (iron (III) chloride) **inorganic (does not contain carbon)**

- 4) In addition to analyzing evidence what other tasks does a forensic scientist have? Circle all that apply. (2)

a) **interpret evidence**

c) **testify in court**

b) chase after bad guys

d) interview suspects

List two basic objectives for the forensic scientist when analyzing physical evidence. (2)

Identify a substance, characterize a substance (more general than identifying), and compare substances to determine if they share a common origin or source.

- 5) Consider the statement: “soil analysis is a comparative science.”
- Why might soil be valuable evidence? (2)
Soil is valuable evidence because of its prevalence at crime scenes and easy transferability from a crime scene to a suspect. Soil is associative evidence (it links a suspect to a crime scene.
 - What is the goal of comparing soil samples? (2)
Samples are compared directly to each other to determine if the samples have a common origin or came from a common source.
 - Where would soil samples be collected from? (2)
Samples collected from a suspect and crime scene or known and unknown. Alibi locations will also be collected.
 - How are soil samples collected? (2)
Soil is collected at regular intervals within a 100 yard radius from the crime scene. Top layers only should be removed (digging too deep isn't necessary). Collected samples are packaged in individually labeled containers. Soil collected from an object is not removed instead the entire object is processed.
 - Briefly describe or list two physical properties used to compare soil samples. (2)
Color, texture, particle size, density distribution, gross appearance, presence of plant or animal material or artificial debris, characterization of minerals or rocks
 - Analysis of what other type of physical evidence from CH 114 so far this term could also be considered comparative? (2)
Glass fragments, ink samples
- 6) A shattered glass jar was found at the scene of a burglary. The density of the glass was determined to be 2.25 g/mL. A glass fragment recovered from a suspect had a mass of 2.567 grams. When the glass fragment was added to a graduated cylinder with 10.00 mL of water, the water level increased to 11.25 mL.
- What is the volume of the glass fragment collected from the suspect? (2)
 $11.25 \text{ mL} - 10.00 \text{ mL} = 1.25 \text{ mL}$
 - What is the density of the glass fragment collected from the suspect? (3)

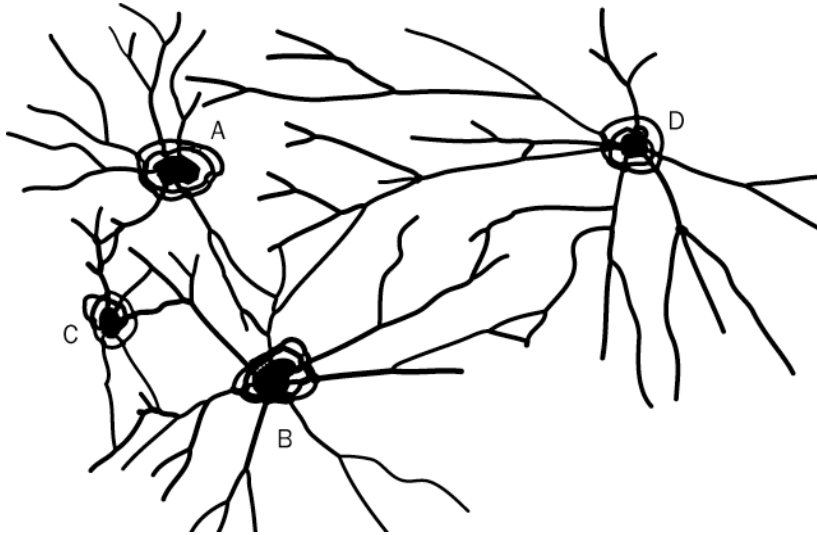
$$\text{Density} = \text{mass} / \text{volume}$$
 $= 2.567 \text{ g} / 1.25 \text{ mL} = 2.05 \text{ g/mL}$
 - Does the glass fragment link the suspect to the crime scene? Briefly explain your answer. (3)
The density of the fragment collected from the suspect has a density of 2.05 g/mL. Compared to the density of the glass collected at the crime scene, the two samples do not appear to share a common origin. 2.05 g/ml does not equal and is not very close to 2.25 g/mL. The densities differ by about 8%,

which according to the article *Chemists Who Unravel Crimes* would be good enough. While the density of glass of the same type can vary, it does not vary by 0.20 g/mL.

- d) What other information would be helpful or necessary to link the glass fragment collected at the crime scene with a sample collected from a potential suspect? Briefly discuss the strengths or limits of each. (3)

The refractive index or at least a comparison of refractive indexes of the two samples would be helpful, along with a physical description of the two pieces in terms of color, thickness, clarity, etc. A physical match of the two pieces would be the only conclusive match or a common origin.

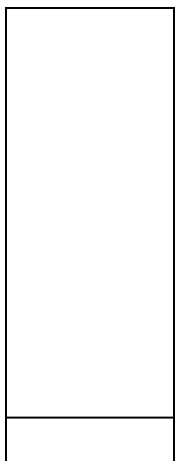
- 7) A diagram of a piece of window glass with suspected holes made from thrown rocks is brought into the lab for analysis (see below).



- a) On the diagram clearly identify one concentric fracture and one radial fracture. **Any circular break is a concentric fracture. Any linear crack is a radial fracture.**
- b) Assuming each hole was formed by a rock, determine the order the rocks were thrown. Briefly explain your reasoning for each. (4)
D was first, it does not terminate at any other fractures. B was next, it terminates at D and C and A both terminate at B. C was next and A was last. A terminates at C. The overall order is D, B, C, A.
- c) What two types of evidence would you look for to determine if the rocks were thrown at the window from the inside or outside of the house? Briefly explain your answer. (4)
You would measure the size of the concentric fracture on each side of the glass. The exit side is larger. Also, you could examine the edge of a radial fracture and use the 3-R rule to determine direction of impact. The striations on the radial fracture make right angles on the reverse side.

8) A sample of ink was analyzed using thin-layer chromatography (TLC).

- a) Analysis of the ink showed a blue spot with an R_f of 0.95, an orange spot with an R_f of 0.60 and a yellow spot with an R_f of 0.25. Using the TLC plate to the left, draw a diagram of the developed TLC plate for the ink sample. Clearly label the origin, solvent front and color of each spot. (5)



The blue spot has the greatest R_f and therefore travels the farthest up the plate and is close to the solvent front. The orange spot has moved half way between the origin and the solvent front. The yellow spot has the smallest R_f and therefore moved the least. It's R_f is 0.25 so it moved a quarter of the distance the solvent front moved.

- b) Using the description of the ink sample above give an example of each of the following: (2)

a quantitative observation: any of the R_f values (numbers)

a qualitative observation: any of the colors, blue, orange, yellow

- c) Which component of the ink has the greatest affinity for the mobile phase? (2)
The blue spot with the largest R_f ; it moved the farthest up the plate.

9) All elements are composed of atoms. How are atoms of mercury (Hg) different than atoms of neon (Ne)? (2)

- a) The atoms have different masses.
b) The atoms have a different number of protons.
c) The atoms have a different number of neutrons.
d) The atoms have different colors.

10) Is neon (Ne) a metal, **nonmetal** or metalloid? Circle your answer. (1)

11) Which of the following statements is false? (2)

- a) Protons and neutrons make up the nucleus of an atom.
b) A neutron is charge neutral (has no charge).
c) Protons and electrons give the atom its mass.
d) A proton has a charge of positive one (+1).
e) An atom contains equal numbers of protons and electrons.

- 12) Thallium (Tl) is a component of rat poison. Thallium has two known isotopes, thallium-203 and thallium-205. How many protons, neutrons and electrons does each isotope of thallium contain? (4)

Thallium has 81 protons and 81 electrons. The isotopes differ in the mass and therefore the number of neutrons. Thallium-203 has $203 - 81 = 122$ neutrons, thallium-205 has 124 neutrons.

Answer **one** of the following two questions. (5)

- 13) Briefly explain how a density gradient works, why a density gradient may be used in a forensic lab and the limitations of using a density gradient.

Density gradients can be used to analyze soil samples (and also glass fragments) for a common origin. To make a density gradient two substances with different densities are mixed in various proportions to create 6 to 10 layers, each with a different density. The bottom layer has the greatest density (and is usually composed of the more dense substance alone) and the top layer is composed of the least dense substance on its own. Each layer in between contains greater proportions of the less dense substance thereby decreasing the density of the layer. When preparing a column the layers must not mix together. When the soil sample is added the dense particles will settle to the lower layers of a column. A soil profile from the scene can be compared to a soil profile from a suspect. Density gradients will be of limited value if the distribution is not unique or if the samples after drying and sieving do not have a uniform composition.

- 14) Briefly explain how a forensic scientist would begin their analysis of a suspected drug and what tests would follow the preliminary analysis. Include in your discussion the strengths or limitations of each test.

The analysis would begin with color or spot tests, chemical tests used to determine if a sample contains a drug and if so what class or family of drug is present. Follow up tests such as TLC, visible, IR or mass spectrometry would uniquely identify the drug. Color tests only identify the class of drug; many drugs in the same class will produce the same results. Visible spectroscopy and TLC will tentatively identify a drug, visible spectroscopy is simple (one peak only) and multiple substances could have the same spectrum. TLC requires comparison to a known sample. IR and mass spectrometry will uniquely identify a substance.

15) Consider the following methods used for analyzing evidence to answer **6 of the 8** following questions. If you answer all parts, only the first six will be graded. (12)

- I. infrared spectroscopy
- II. visible spectroscopy
- III. thin-layer chromatography
- IV. mass spectroscopy
- V. gas chromatography
- VI. emission spectroscopy

a) Which method or methods would provide a unique “fingerprint” of a chemical substance?

I, IV, VI (IR, mass spec, emission)

b) Which method or methods provide qualitative data to tentatively identify an organic substance?

II, III, V (visible, TLC, GC)

c) Which method or methods require relatively pure substances for analysis?

I, II, IV (IR, visible, mass spec)

d) Which method or methods work well for multi-component substances?

III, V, VI (TLC, GC, emission)

e) Which method or methods use a mobile and stationary phase for analysis?

III, V (TLC, GC)

f) Which method or methods are used to analyze inorganic substances?

VI (emission)

g) Which method or methods measure the selective absorption of radiation by a chemical substance?

I, II (IR, visible)

h) Which method or methods measure the selective emission of radiation by a chemical substance?

VI (emission)

- 16) Briefly explain what Locard's exchange principle is and why the principle is significant for the forensic scientist.

Locard's exchange principle states when two objects come in contact with each other there will be a transfer of material between them (a cross transfer). The transfer of material at the crime scene to the criminal provides the forensic scientist physical evidence for comparison connecting the criminal to the crime scene.

- 17) Briefly explain the purpose of a standard or reference sample. Given an example and include where the reference or standard would be collected from and how the sample would be used by a forensic scientist.

A standard or reference sample is a pure sample of known identity. It provides the forensic scientist a "known" for comparison of other samples collected from the suspect or crime scene. A pure, known sample of a drug or a piece of glass collected from a broken window at a crime scene would be examples.

- 18) Briefly explain how density and refractive index can be used in forensic science.

Density and refractive index are both physical properties commonly used to characterize and compare glass fragments. Together they may link a sample to a common source or in the absence of comparable density and refractive index values a common source may be excluded.

- 19) Briefly explain what functional groups are, if functional groups are organic or inorganic and how a forensic scientist uses functional groups.

Functional groups are characteristic structural features of organic molecules. The unique arrangements of carbon atoms with hydrogen, oxygen and nitrogen show similar behavior as a group of atoms. Functional groups undergo similar chemical reactions and their identification can be used to classify organic compounds. Color or spot tests work because classes of drugs contain similar functional groups. The functional groups react by producing a specific color when particular reagents are added. IR spectra are unique because each functional group absorbs light selectively at different wavelengths.

- 20) How are ultraviolet and infrared spectroscopy used to identify organic compounds? Is one a superior method for identifying an unknown organic substance? Briefly explain your answer.

In each type of spectrophotometry the amount of light absorbed is measured as a function of wavelength or frequency. The supplied light source is either in the UV region of the electromagnetic spectrum or the IR region. A UV spectrum is relatively simple, showing one major peak of maximum absorbance and provides a tool for a probable identification of an unknown; the results are not definitive. For an IR spectrum, a more complex absorption pattern occurs with multiple peaks. The complexity of the spectrum allows for IR to be used to definitively identify an unknown. Different substances each have their own IR spectrum making an IR spectrum a fingerprint for a substance and therefore a superior method for identification.

21) What are trace elements? Are trace elements organic or inorganic? How are trace elements used for forensic analysis of physical evidence?

Trace elements are present in small quantities, typically less than 1% and represent a unique feature of a sample. Trace elements are inorganic. Chemical analysis may identify what a substance is but just because two samples are made from the same elements does not mean the samples share a common origin. Analysis of trace elements provides a meaningful criterion for at least increasing the probability of two samples originating from the same source. Trace elements serve as invisible markers that may establish the sources of a material or at least provide additional points of comparison.

22) Briefly explain two similarities and two differences between the CH 114 spectroscopy lab (gas lamps and flame tests) and inductively coupled plasma-optical emission spectroscopy (ICP-OES) used to analyze silicon content in suspected cremains discussed in class.

In both cases energy is added and the electrons excited. When the electrons return to lower energy levels they release energy in the visible portion of the electromagnetic spectrum. In ICP-OES the temperatures are about three times hotter than a flame. The higher temperature causes the electrons to reach a higher-energy excited state and makes it possible to detect elemental concentrations as low as 1 ppb. The temperatures of our lab were not high enough to allow detection of such low concentrations.

23) During our discussion of different types of evidence, the phrase “high evidential value” has been used. Briefly explain what “high evidential value” means by giving an example of how a specific piece of evidence would be analyzed to maximize the evidential value of it.

A single piece of evidence is analyzed in multiple ways or many pieces of evidence are analyzed differently. An unknown drug for example could be subjected to color tests for a tentative ID, it could be run beside a known sample on TLC for a tentative ID, its visible spectrum could be taken also for a tentative ID and finally a mass spec or IR spectra could be determined, both of which are unique to the substance. One sample is tested in many ways. Another way to provide high evidential value was described in the Sarah Payne case. Many pieces of evidence were considered together and provided more value together than any single piece individually.

Question Replacement: you may choose to select one additional question from the list above to replace any 4 to 6 point question on the exam. Please clearly indicate which question you are answering from those above and which question you want it to replace, in addition to answering the question. You may select a multiply part question for replacement.

Question # ____ will replace question # ____.