

# CHEM 1A Winter 2021: Sample Final

Lecturer: Prof. Fokwa

March 17, 2021

Time: 3 h

*Please note: This test has a total of 400 points (Parts I, II and III) and 15 pts bonus questions (Part IV). The test covers chapters 1-7.*

**Allowed for the test are: a blank paper sheet, a copy of the periodic table given on the sample final and below, a pen and a scientific calculator (non-graphing).**

## Part I: Chapters 1, 2 and 3: 27 Multiple Choices (5 pts each; 135 pts in total)

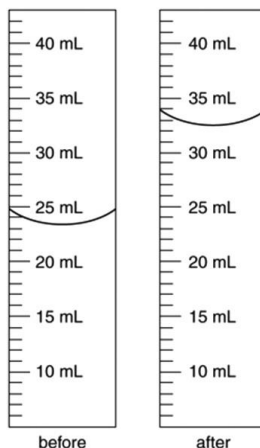
- \_\_\_\_\_ 1.  $^1\text{H}$ ,  $^2\text{H}$ , and  $^3\text{H}$  are examples of \_\_\_\_\_ because they have different numbers of \_\_\_\_\_.  
a. isotopes; protons  
**b. isotopes; neutrons**  
c. isotopes; electrons  
d. allotropes; neutrons  
e. allotropes; protons
- \_\_\_\_\_ 2. Molecules are represented in various ways. Which statement A–D about molecular representations is *not* correct.  
a. A molecular or chemical formula identifies the elements and the number of atoms of each that comprise a molecule of a compound.  
b. A structural formula shows how the atoms are bonded together but does not necessarily indicate the bond angles or three-dimensional shape of the molecule.  
c. A ball-and-stick model shows bond angles and the three-dimensional shape of a molecule.  
d. A space-filling model best represents the size of the atoms and distribution of electrons in a molecule.  
**e. Statements A–D all are correct.**
- \_\_\_\_\_ 3. Which of the following processes is a chemical reaction?  
a. distillation  
**b. combustion**  
c. filtration  
d. condensation  
e. sublimation
- \_\_\_\_\_ 4. Identify the binary compound that has ionic bonding.  
a.  $\text{H}_2\text{O}$   
b.  $\text{NO}$   
**c.  $\text{LiF}$**   
d.  $\text{CH}_4$   
e.  $\text{CF}_4$
- \_\_\_\_\_ 5. Which of the following mixtures can be separated by filtration?  
a. sugar dissolved in coffee  
**b. sand and water**  
c. gasoline  
d. alcohol dissolved in water  
e. air
- \_\_\_\_\_ 6. Cheetahs can run at speeds of up to 60 mi per hour. How many seconds does it take a cheetah to run 10 m at this speed? (1 mi = 1.609 km)  
**a. 0.37 s**  
b. 0.10 s  
c. 56 s  
d. 18 s  
e. 0.43 s

Sample

7. Which of the following is *not* a pure substance?

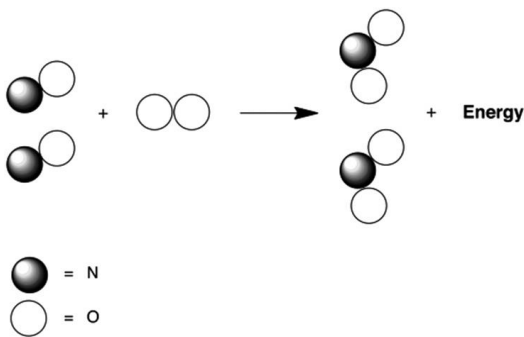
- a. Air
- b. nitrogen gas
- c. oxygen gas
- d. argon gas
- e. table salt (sodium chloride)

8. An irregularly shaped metal object with a mass of 25.43 g was placed in a graduated cylinder with water. The before and after volumes are shown below. What is the density of the metal?



- a. 2.8 g/cm<sup>3</sup>
- b. 2.906 g/cm<sup>3</sup>
- c. 0.782 g/cm<sup>3</sup>
- d. 0.344 g/cm<sup>3</sup>
- e. 2.734 g/cm<sup>3</sup>

9. Which statement A–D about the reaction of nitrogen monoxide with oxygen, which is called combustion and is represented below by the following cartoon, is *not* correct? The reaction product is nitrogen dioxide.



- a. Two molecules of nitrogen monoxide combine with one molecule of oxygen.
- b. Two atoms of nitrogen combine with four atoms of oxygen to produce two molecules of nitrogen dioxide.
- c. The equation is balanced because the number of atoms of each element does not change.
- d. The products are two molecules of nitrogen dioxide and released energy.
- e. Statements A–D all are correct.

10. Which one of the following statements is *not* correct?

- a. Sodium and chlorine are elements.
- b. Sodium chloride (table salt) is a compound.
- c. Sodium chloride is a pure substance.
- d. Sodium chloride is a heterogeneous mixture.
- e. Sodium chloride added to water forms a solution.

Sample

- \_\_\_\_ 11. What is the symbol of the ion having 12 protons and 10 electrons?  
 a.  $\text{Mg}^{2+}$  d.  $\text{Na}^{2+}$   
 b.  $\text{Al}^{3+}$  e.  $\text{Mg}$   
 c.  $\text{Mg}^{2-}$
- \_\_\_\_ 12. The two major isotopes of bromine are  $^{79}\text{Br}$  and  $^{81}\text{Br}$ . Assume that the masses of the  $^{79}\text{Br}$  and  $^{81}\text{Br}$  isotopes are 79.00 u and 81.00 u, respectively. The weighted average atomic mass of bromine is 79.90 u. What are the relative % abundances of each isotope? Estimate without detailed calculations!

Choice	% Abundance of $^{79}\text{Br}$	% Abundance of $^{81}\text{Br}$
A	79.0%	21.0%
B	19.0%	81.0%
C	35.1%	64.9%
D	55.0%	45.0%
E	47.0%	53.0%

- a. Choice A d. **Choice D**  
 b. Choice B e. Choice E  
 c. Choice C
- \_\_\_\_ 13. Which one of the following statements is *not* consistent with Dalton's atomic view of matter?  
 a. **Atoms of one element can be converted into atoms of another element.**  
 b. Each element is composed of atoms that are identical in size, mass, and chemical properties.  
 c. Compounds are formed from different atoms in simple whole number ratios.  
 d. Atoms of different elements can combine in several different proportions to make different compounds.  
 e. Matter is discrete, as proposed by Democritus.
- \_\_\_\_ 14. Which statement A–D regarding the terms mole and molar mass is *not* correct?  
 a. A mole is defined as the number of particles in exactly 12 g of carbon-12.  
 b. A mole of oxygen gas contains  $6.022 \times 10^{23}$  molecules.  
 c. Two moles of oxygen atoms can be obtained by decomposing one mole of carbon dioxide.  
 d. To obtain the molar mass in grams (g/mol) from the atomic mass in atomic mass units(u), multiply by  $6.022 \times 10^{23}$ /mol and divide by  $6.022 \times 10^{23}$  u/g.  
 e. **Statements A–D all are correct.**
- \_\_\_\_ 15. How many moles of ammonia are there in a 346 g sample of pure  $\text{NH}_3$  (17.03 g/mol)?  
 a. 0.0496 mol d. 5,930 mol  
 b. **20.3 mol** e. 3.46 mol  
 c. 24.7 mol
- \_\_\_\_ 16. How many atoms of each element are there in the compound  $\text{Na}_3(\text{PO}_4)_3$ ?  
 a. **sodium 3, phosphorus 3, oxygen 12**  
 b. sodium 9, phosphorus 3, oxygen 12  
 c. sodium 3, phosphorus 1, oxygen 4  
 d. sodium 3, potassium 1, oxygen 4

## Sample

- \_\_\_\_\_ 17. Based on the element's position in the periodic table, which statement below is *not* correct?
- a. The charge on an ion of sodium is 1+.
  - b. The charge on an ion of magnesium is 2+.
  - c. The charge on an ion of oxygen is 2-.
  - d. The charge on an ion of chlorine is 1-.
  - e.  $\text{Mg}^{2+}$  has more electrons than Ne.
- \_\_\_\_\_ 18. Based on its position in the periodic table, which atom would you predict to form an ionic compound with two bromine atoms?
- a. sodium
  - b. aluminum
  - c. lithium
  - d. calcium
  - e. carbon

19. Which element labeled A–E in the periodic table below will have an ionic charge of  $-2$ ?

[illegible]

- a. A  
b. B  
c. C
- d. D  
e. E
20. Which of the following elements would you expect to have the greatest first ionization energy?  
a. Si  
b. S  
c. Na  
d. Mg  
e. Al
21. Calculate the mass, in grams, of 10 copper atoms.  
a. 63.55 g  
b.  $1.055 \times 10^{-21}$  g  
c. 635.5 g  
d.  $3.827 \times 10^{26}$  g  
e.  $1.827 \times 10^{26}$  g
22. What is the wavelength of a photon emitted by a  $\text{Kr}^+$  laser with an energy of  $3.07 \times 10^{-19}$  J?  
a.  $\lambda = 224$  nm  
b.  $\lambda = 389$  nm  
c.  $\lambda = 417$  nm  
d.  $\lambda = 647$  nm  
e.  $\lambda = 534$  nm
23. What is the photon energy of the yellow-orange light ( $\lambda = 589$  nm) produced by sodium vapor?  
a.  $3.37 \times 10^{-19}$  J  
b.  $6.63 \times 10^{-18}$  J  
c.  $2.99 \times 10^{-20}$  J  
d.  $1.45 \times 10^{-17}$  J  
e.  $7.45 \times 10^{-16}$  J

## Sample

- \_\_\_\_\_ 24. What is the wavelength ( $\lambda$ , in m) of a radio station operating at a frequency of 99.6 MHz?
- a.  $3.01 \times 10^6$  m d. 0.332 m  
b. 3.01 m e. 3.32 m  
c.  $3.32 \times 10^{-7}$  m
- \_\_\_\_\_ 25. Which of these regions of the electromagnetic spectrum has the longest wavelength?
- a. Visible d. Ultraviolet  
b. Infrared e. X-rays  
c. Gamma rays
- \_\_\_\_\_ 26. In the summer of 2010, platinum (195.078 g/mol) sold for \$1,500/oz. One ounce is equal to 28.35 g. How many platinum atoms could you buy with a penny (\$0.01)?
- a.  $5.0 \times 10^{20}$  atoms d.  $1.5 \times 10^{18}$  atoms  
b.  $2.6 \times 10^6$  atoms e.  $5.8 \times 10^{17}$  atoms  
c.  $6.5 \times 10^{19}$  atoms
- \_\_\_\_\_ 27. What is the ground state electron configuration for selenium (Se)?
- a.  $[\text{Ar}]4d^{10}4p^4$  d.  $[\text{Ar}]4s^23d^{10}4p^4$   
b.  $1s^22s^22p^63s^23d^{10}3p^54s^44p^4$  e.  $1s^22s^22p^5$   
c.  $[\text{Kr}]4p^4$

**Part II: Chapters 4 and 5: 27 Multiple Choices (5 pts each; 135 pts in total)**

- \_\_\_\_\_ 28. Which of the following is *not* a possible set of quantum numbers for an electron?
- a.  $n = 3, \ell = 2, m_\ell = -1$  d.  $n = 1, \ell = 0, m_\ell = 0$   
b.  $n = 2, \ell = 2, m_\ell = 0$  e.  $n = 2, \ell = 1, m_\ell = 1$   
c.  $n = 4, \ell = 1, m_\ell = 1$
- \_\_\_\_\_ 29. A certain shell is known to have a total of 16 orbitals. Which shell is it?
- a.  $n = 4$  c.  $n = 8$   
b.  $n = 16$  d.  $n = 2$
- \_\_\_\_\_ 30. What is the ground-state electron configuration of a  $\text{Cl}^-$  ion?
- a.  $1s^2 2s^2 2p^6 3s^2 3p^4$  d.  $1s^2 2s^2 2p^6 3s^2 3p^2$   
b.  $1s^2 2s^2 2p^6 3s^2 3p^5$  e.  $1s^2 2s^2 2p^6 3s^2 3p^8$   
c.  $1s^2 2s^2 2p^6 3s^2 3p^6$
- \_\_\_\_\_ 31. If the principal quantum number is seven ( $n = 7$ ) and the angular momentum quantum number is three ( $\ell = 3$ ), which of the following values is *not* an allowed value of the magnetic quantum number ( $m_\ell$ )?
- a. 0 d. -3  
b. 1 e. 4  
c. 2
- \_\_\_\_\_ 32. What is the correct name for  $\text{FeCl}_3$ ? Fe is a transition element.
- a. iron chloride d. ferric trichloride  
b. iron trichloride e. iron (III) chloride  
c. ferrum trichloride

Sample

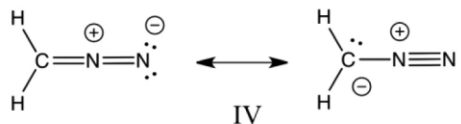
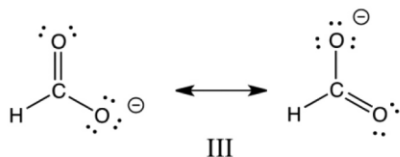
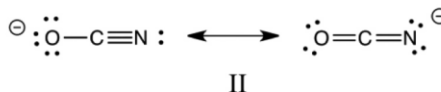
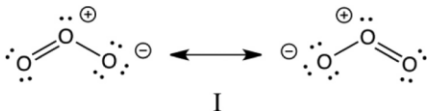
33. Which of the following molecular compounds has an *incorrect* formula or is *not* named correctly?
- $\text{CCl}_4$ , carbon tetrachloride
  - $\text{P}_2\text{N}_5$ , phosphorus pentanitride
  - $\text{SF}_6$ , sulfur hexafluoride
  - $\text{NO}_2$ , nitrogen dioxide
  - $\text{SO}$ , sulfur monoxide
34. Which one of these formula–name combinations is *not* correct?
- diphosphorus tetroxide:  $\text{P}_2\text{O}_4$
  - tetraphosphorus nanoxide:  $\text{P}_4\text{O}_9$
  - diphosphorus pentoxide:  $\text{P}_2\text{O}_5$
  - tetraphosphorus heptoxide:  $\text{P}_4\text{O}_6$
  - phosphorus monoxide:  $\text{PO}$
35. Zinc oxide is found in ointments for the skin. What formula best describes this compound, which has Zn as a doubly charged cation?
- $\text{ZnO}$
  - $\text{Zn}_2\text{O}$
  - $\text{ZnO}_2$
  - $\text{Zn}_2\text{O}_2$
  - $\text{Zn}_2\text{O}_3$
36. Which statement provides the best description of a covalent bond?
- A high electron density between two positively charged atomic nuclei serves to attract the nuclei to each other.
  - The negative charge on one atom is attracted to the positive charge on a second atom.
  - Two or more electrons are attracted to each other, thereby holding the atoms together.
  - Two atomic nuclei are attracted to each other by the strong nuclear force.
  - Two atomic nuclei are attracted to each other by the Coulomb force.
37. The formula for a lutetium carbonate compound is  $\text{Lu}_2(\text{CO}_3)_3$ . What would be the formula for a lutetium nitrate compound given that the charge of lutetium is the same in both compounds?
- $\text{LuNO}_3$
  - $\text{Lu}(\text{NO}_3)_2$
  - $\text{Lu}(\text{NO}_3)_3$
  - $\text{Lu}_2\text{NO}_3$
  - $\text{Lu}_2(\text{NO}_3)_3$
38. Which statement about  $\sigma$  and  $\pi$  bonds is correct?
- A  $\pi$  bond is twice as strong as a  $\sigma$  bond.
  - A  $\pi$  bond has cylindrical symmetry about the internuclear axis.
  - A  $\pi$  bond, as in ethylene, is described by the overlap of hybridized atomic orbitals.
  - A double bond, as in ethylene ( $\text{C}_2\text{H}_4$ ), consists of a  $\pi$  bond and a  $\sigma$  bond.
  - Hydrogen forms  $\pi$  bonds when it bonds to other atoms.
39. Which of the following is an example of a nonpolar covalent bond?
- $\text{C—S}$
  - $\text{Na—Na}$
  - $\text{O—F}$
  - $\text{C—C}$
  - $\text{C—O}$
40. The following Lewis symbol corresponds to which ion?



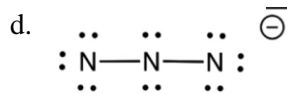
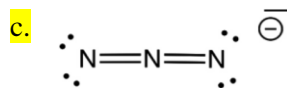
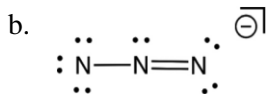
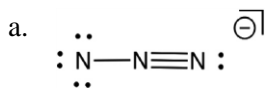
- $\text{F}^-$
- $\text{O}^-$
- $\text{C}^{2-}$
- $\text{B}^{3+}$
- $\text{N}^{2-}$

Sample

41. Which of the following has the most valence electrons?  
 a. HF  
 b. NS  
 c.  $\text{CN}^-$   
 d.  $\text{ArF}$   
 e.  $\text{ArF}^+$
42. How many lone pairs are there in  $\text{ClO}^-$ ?  
 a. 1  
 b. 2  
 c. 3  
 d. 4  
 e. 6
43. Indicate which molecule contains the largest number of nonbonding electrons.  
 a.  $\text{H}_2$   
 b. CO  
 c.  $\text{N}_2$   
 d. NO  
 e.  $\text{O}_2$
44. What types of bonds form between the chlorine and oxygen atoms of the chlorite ion ( $\text{ClO}_2^-$ ) to minimize the formal charge?  
 a. single  
 b. between single and double  
 c. double  
 d. triple  
 e. ionic
45. Resonance structures indicate that \_\_\_\_\_  
 a. there is more than one allotropic form of a compound.  
 b. more than one ionic form of a compound exists.  
 c. the electronic structure is an average or superposition of the diagrams.  
 d. more than one isotopic form of an element exists in the molecule.  
 e. the molecule jumps back and forth between two or more different electronic structures.
46. Which of the following pairs of Lewis structures are *not* resonance structures of one another?

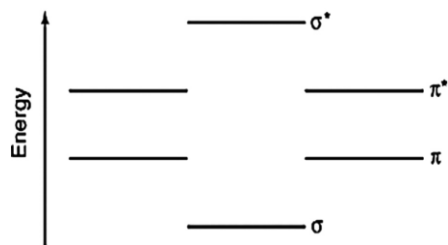


- a. I  
 b. II  
 c. III  
 d. IV  
 e. All pairs are resonance structures.
47. Based on consideration of formal charges, which of the following is the most stable Lewis structure for the azide ion ( $\text{N}_3^-$ )?



Sample





- \_\_\_ 48. The  $\text{Fe}^{3+}$  transition metal ion has how many  $d$  electrons?  
 a. 0  
 b. 3  
 c. 4  
 d. 5  
 e. 8
- \_\_\_ 49. Which arrangement is in the correct order of increasing radii?  
 a.  $\text{Cs} < \text{Mn}^{2+} < \text{Mn}$   
 b.  $\text{Ra} < \text{Li} < \text{Li}^+$   
 c.  $\text{P} < \text{P}^{3-} < \text{As}^{3-}$   
 d.  $\text{Cr} < \text{Cr}^{3+} < \text{Ca}$   
 e.  $\text{H} < \text{He}^+$
- \_\_\_ 50. Which arrangement is *not* in the correct order of decreasing first ionization energy?  
 a.  $\text{B} > \text{Al} > \text{In}$   
 b.  $\text{As} > \text{P} > \text{N}$   
 c.  $\text{Cl} > \text{Si} > \text{Na}$   
 d.  $\text{Li} > \text{K} > \text{Cs}$   
 e.  $\text{Br} > \text{As} > \text{Ga}$
- \_\_\_ 51. Which bond is the least polar?  
 a.  $\text{H}-\text{C}$   
 b.  $\text{H}-\text{N}$   
 c.  $\text{H}-\text{O}$   
 d.  $\text{H}-\text{Cl}$   
 e.  $\text{H}-\text{F}$
- \_\_\_ 52. How many of these atoms or ions have no unpaired electrons?  
 $\text{N}, \text{O}, \text{Na}^+, \text{N}^{3-}, \text{Sc}$   
 a. 1  
 b. 2  
 c. 3  
 d. 4  
 e. 5
- \_\_\_ 53. Which statement about  $\sigma$  and  $\pi$  bonds is correct?  
 a. A  $\pi$  bond is twice as strong as a  $\sigma$  bond.  
 b. A  $\pi$  bond has cylindrical symmetry about the internuclear axis.  
 c. A  $\pi$  bond, as in ethylene, is described by the overlap of hybridized atomic orbitals.  
 d. A double bond, as in ethylene ( $\text{C}_2\text{H}_4$ ), consists of a  $\pi$  bond and a  $\sigma$  bond.  
 e. Hydrogen forms  $\pi$  bonds when it bonds to other atoms.
- \_\_\_ 54. Using the energy-level diagram for valence orbitals below, determine the bond order of the PO molecule.



- a. 2  
 b. 2.5  
 c. 1.5  
 d. 1  
 e. 0.5



**Part III: Chapters 6 and 7: 26 Multiple Choices (5 pts each; 130 pts in total)**

- \_\_\_\_ 55. Which of the following compounds is capable of dipole–dipole interactions?
- $\text{CH}_4$
  - $\text{CO}_2$
  - $\text{H}_2\text{CO}$
  - $\text{SF}_6$
  - $\text{NH}_4^+$
- \_\_\_\_ 56. Which of the following polar compounds is likely to have the highest boiling point?
- $\text{CH}_3\text{OCH}_3$
  - $\text{CH}_3\text{CH}_2\text{OH}$
  - $(\text{CH}_3)_2\text{CO}$
  - $\text{H}_2\text{CO}$
  - $\text{CO}$
- \_\_\_\_ 57. Which of the following compounds would you most appropriately call hydrophobic?
- $\text{CH}_4$
  - $\text{H}_2\text{CO}$
  - $\text{CO}$
  - $\text{HCl}$
  - $\text{NaCl}$
- \_\_\_\_ 58. Based on the given P-T phase diagram which of the following substances has a solid that is less dense than the liquid?
- 
  - 
  - 
  - 
- \_\_\_\_ 59. Which alkane compound has the lowest vapor pressure?
- $\text{C}_4\text{H}_{10}$
  - $\text{C}_5\text{H}_{12}$
  - $\text{C}_6\text{H}_{14}$
  - $\text{C}_7\text{H}_{16}$
  - $\text{C}_8\text{H}_{18}$
- \_\_\_\_ 60. Which of the following compounds would be most soluble in carbon tetrachloride,  $\text{CCl}_4$ ?
- $\text{H}_2\text{O}$
  - $\text{CH}_3\text{OH}$
  - $\text{NH}_3$
  - $\text{C}_6\text{H}_6$
  - $\text{HCl}$
- \_\_\_\_ 61. The resistance of a liquid to an increase in its surface area is \_\_\_\_.
- surface tension.
  - viscosity.
  - capillary action.
  - a meniscus.
  - impossible.

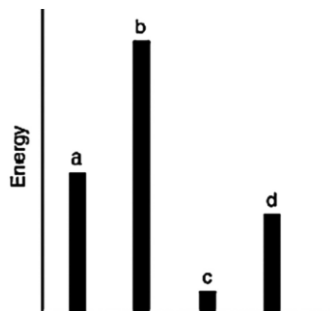
Sample

62. Which is the dominant interaction that leads to the formation of a hydration sphere in a salt solution?
- ion-ion
  - ion-dipole
  - dipole-dipole
  - hydrogen bonding
  - dispersion or London forces

63. Which compound do you predict has the lowest boiling point?
- CH<sub>4</sub>
  - NH<sub>3</sub>
  - HF
  - H<sub>2</sub>O
  - HI

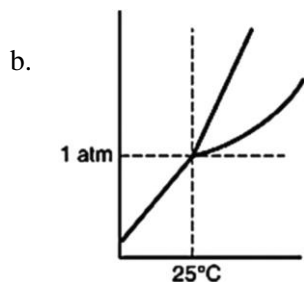
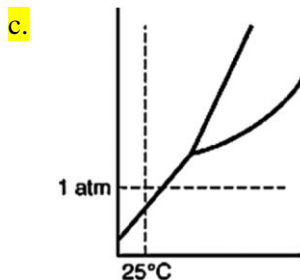
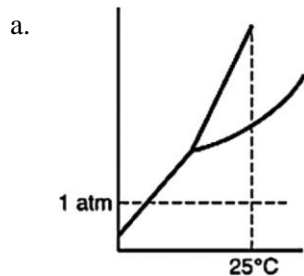
64. Boiling points increase in the order HCl < HBr < HI because \_\_\_\_\_ contribute to the intermolecular interactions.
- dispersion forces
  - dipole-dipole forces
  - ion-ion forces
  - ion-dipole forces
  - hydrogen-bonding forces

65. The relative energies (strengths) of the intermolecular forces present in each of four different pure substances are shown in the figure below. Which substance has the highest melting point?



- a
- b
- c
- d

66. Which of the following substances is a solid at 25°C and 1 atm?



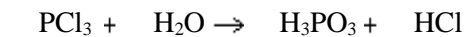
- d. None of these substances are solid under these conditions.

Sample

67. The acid–base reaction between phosphoric acid,  $\text{H}_3\text{PO}_4$ , and calcium hydroxide,  $\text{Ca}(\text{OH})_2$ , yields water and calcium phosphate. For each mole of calcium phosphate produced by this reaction, how many moles of water are produced?

a. 1  
b. 2  
c. 3  
d. 4  
e. 6

68. Phosphorus trichloride reacts with water to form phosphorous acid,  $\text{H}_3\text{PO}_3$ , and hydrochloric acid in the following unbalanced reaction. For each mole of phosphorous acid produced by this reaction, how many moles of  $\text{HCl}$  are produced?



a. 1  
b. 2  
c. 3  
d. 4  
e. 5

69. Burning coal that contains sulfur releases sulfur dioxide gas into the atmosphere, where it combines with water to form sulfurous and sulfuric acid, thereby producing acid rain. Assume sulfur in coal is in the form of pyrite ( $\text{FeS}_2(s)$ ), which reacts with molecular oxygen to produce  $\text{Fe}_2\text{O}_3(s)$  and  $\text{SO}_2(g)$ . Write the balanced equation for this reaction and report the sum of the stoichiometric coefficients, written as integers.

a. 16  
b. 14  
c. 23  
d. 25  
e. 18

70. Water can be separated into its elements according to the following equation by electrolysis. If 20.0 g of water is decomposed by this method, how much oxygen gas is produced?



a. 17.8 g  
b. 8.9 g  
c. 35.6 g  
d. 16.0 g  
e. 10.0 g

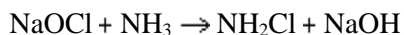
71. Fool's Gold is the mineral pyrite ( $\text{FeS}_2$ ). What is the mass percent of sulfur in pyrite?

a. 36.44%  
b. 46.59%  
c. 49.09%  
d. 53.41%  
e. 63.56%

72. One form of asbestos called chrysotile is considered to be a human carcinogen. Mass analysis reveals that it has the empirical formula  $\text{Mg}_3\text{Si}_2\text{H}_4\text{O}_9$ . If the molar mass is 831 g/mol, which molecular formula is correct?

a.  $\text{MgSiO}_4(\text{OH})_2$   
b.  $\text{Mg}_2\text{Si}_4\text{O}_8(\text{OH})_4$   
c.  $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$   
d.  $\text{Mg}_6\text{Si}_4\text{O}_{10}(\text{OH})_8$   
e.  $\text{Mg}_9\text{Si}_6\text{O}_{15}(\text{OH})_{12}$

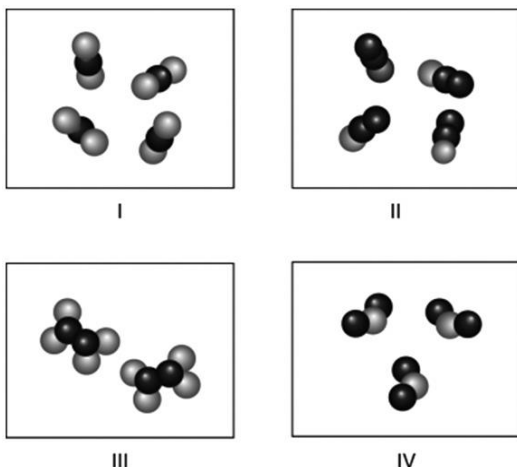
73. Household bleach contains 5.0% sodium hypochlorite ( $\text{NaOCl}$ ) by mass. Household ammonia contains 5.0%  $\text{NH}_3$  by mass. If 50.00 g of bleach are mixed with 50.00 g of 5.0% ammonia, what mass of the toxic chloramine gas would be produced by the following reaction?



a. 5.0 g  
b. 2.5 g  
c. 1.7 g  
d. 7.6 g  
e. 3.2 g

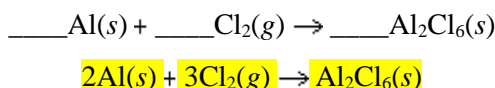
Sample

74. Which molecules shown below have the same molecular formula?



- a. Only I and II  
b. Only I and IV  
c. I, II, and IV  
d. Only II and IV  
e. All are different

75. Dialuminum hexachloride,  $\text{Al}_2\text{Cl}_6$  (266.66 g/mol), is an inexpensive compound that is used in many industrial processes. It is made by treating scrap aluminum with chlorine gas. If a reaction is run with 270 g of aluminum and 710 grams of chlorine, the limiting reactant is \_\_\_\_\_, and the theoretical yield is \_\_\_\_\_ of  $\text{Al}_2\text{Cl}_6$ . Balance the reaction equation first.



- a. Al; 890 g  
b.  $\text{Cl}_2$ ; 890 g  
c. Al; 1,300 g  
d.  $\text{Cl}_2$ ; 1,300 g  
e.  $\text{Cl}_2$ ; 2,700 g

76. A 10.00 g sample of a hydrocarbon (which is a compound that contains only carbon and hydrogen) was burned in oxygen, and the carbon dioxide and water produced were carefully collected and weighed. The mass of the carbon dioxide was 30.50 g, and the mass of the water was 14.98 g. What was the empirical formula of the hydrocarbon?

- a.  $\text{C}_5\text{H}_{12}$   
b.  $\text{C}_1\text{H}_6$   
c.  $\text{C}_1\text{H}_3$   
d.  $\text{C}_5\text{H}_6$   
e.  $\text{C}_1\text{H}_2$

77. Chlorhexidine is an antibacterial drug found in mouthwash and has an elemental analysis of 52.28% carbon, 5.98% hydrogen, 14.03% chlorine, and 27.71% nitrogen. It has a molar mass of 505.45 g/mol. What is the molecular formula of chlorhexidine?

- a.  $\text{C}_{11}\text{H}_{15}\text{ClN}_5$   
b.  $\text{C}_{22}\text{H}_{30}\text{Cl}_2\text{N}_{10}$   
c.  $\text{C}_{10}\text{H}_{15}\text{ClN}_6$   
d.  $\text{C}_{20}\text{H}_{30}\text{Cl}_2\text{N}_{12}$   
e.  $\text{C}_{30}\text{H}_{45}\text{Cl}_3\text{N}_{18}$

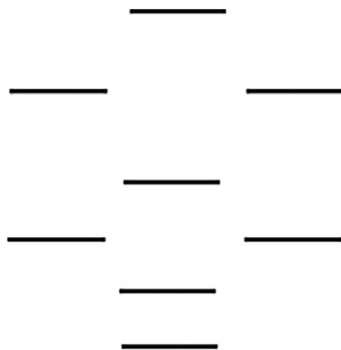
Sample

- \_\_\_\_\_ 78. Allicin, a potent antibacterial compound, is formed by the enzyme alliinase when garlic is chopped or damaged. Allicin contains carbon, hydrogen, oxygen, and sulfur atoms. In combustion analysis, a 10.00 mg sample of allicin produced 16.27 mg of CO<sub>2</sub>, 5.55 mg of water, and 7.90 mg of SO<sub>2</sub>. What is the empirical formula of allicin?
- a. **C<sub>6</sub>H<sub>10</sub>S<sub>2</sub>O**
  - b. C<sub>3</sub>H<sub>5</sub>SO
  - c. C<sub>12</sub>H<sub>20</sub>S<sub>4</sub>O
  - d. C<sub>6</sub>H<sub>10</sub>SO
  - e. The moles of oxygen in the sample cannot be determined, so the empirical formula cannot be determined.
- \_\_\_\_\_ 79. At the Tesla automotive factory, a Model S sedan is built using 4 tires, a main chassis, and 5 lithium ion batteries. How many sedans can be made if there are 17 tires, 5 chassis, and 22 batteries?
- a. 2
  - b. 3
  - c. **4**
  - d. 5
  - e. 6
- \_\_\_\_\_ 80. A reaction vessel contains equal masses of solid magnesium metal and oxygen gas. The mixture is ignited and burns with a burst of light and heat, producing solid MgO. The mass of the MgO is less than the initial mass of the magnesium and oxygen. What is your explanation for this apparent loss of mass?
- a. Conservation of mass is violated in this reaction.
  - b. Some of the mass was converted into energy (heat and light) as  $E = mc^2$ .
  - c. **Not all of the oxygen reacted.**
  - d. Not all of the magnesium reacted.
  - e. Measurement must be in error because mass is conserved in chemical reactions.

**Part IV: Bonus Questions (5 pts each; 15pts in total)**

81. Calcite has a chemical formula of  $\text{CaCO}_3$ , and one gram occupies approximately  $0.369 \text{ cm}^3$ . Pyrite ( $\text{FeS}_2$ ) is 1.8 times denser than calcite. What is the density of  $\text{FeS}_2$ ?
- $2.7 \text{ g/cm}^3$
  - $0.66 \text{ g/cm}^3$
  - $4.9 \text{ g/cm}^3$
  - $2.2 \text{ g/cm}^3$
  - $1.5 \text{ g/cm}^3$

82. According to the molecular orbital energy-level diagram below, which one of the following statements is *not* correct about  $\text{NO}$ ,  $\text{NO}^+$ , and  $\text{NO}^-$ ? These molecular orbitals are formed from the  $2s$  and  $2p$  atomic orbitals.



- The bond order in  $\text{NO}$  is 2.5.
  - $\text{NO}^+$  has the shortest bond.
  - Only one of these species is paramagnetic.
  - The bond order in  $\text{NO}^-$  is 2.0.
  - $\text{NO}^-$  has the weakest bond.
83. Which of the following liquids will have the highest surface tension?
- dimethylamine,  $(\text{CH}_3)_2\text{NH}$
  - dimethylsulfide,  $(\text{CH}_3)_2\text{S}$
  - water,  $\text{H}_2\text{O}$
  - 1-propanol,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
  - ethylene glycol,  $\text{HOCH}_2\text{CH}_2\text{OH}$

## Sample

### Useful equation, constants, and conversions:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$c = \lambda \nu (\lambda \text{ is wavelength; } \nu \text{ is frequency; } c = 2.998 \times 10^8 \text{ m/s})$$

$$E = h\nu \quad E = \frac{hc}{\lambda} ; \quad \lambda = \frac{hc}{E} = \frac{hc}{mc^2} = \frac{h}{mc} = \frac{h}{mu}$$

$$\frac{1}{\lambda} = (1.097 \times 10^{-2} \text{ nm}^{-1}) \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) ; \quad \Delta E = -2.178 \times 10^{-18} \text{ J} \left( \frac{1}{n_{\text{final}}^2} - \frac{1}{n_{\text{initial}}^2} \right)$$

$$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} \text{ (Planck's constant); Avogadro's number } N = 6.022 \times 10^{23} / \text{mol}$$

$$KE_{\text{electron}} = h\nu - \Phi, \text{ where } \Phi = \text{work function.}$$

$$\text{Mean: } \bar{x} = \frac{\sum_i (x_i)}{n} ; \quad \text{Standard deviation(s): } s = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{n-1}}$$

$$\text{Percent Yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$\text{Beer's law: } A = \epsilon \cdot b \cdot c$$

$$\text{Molarity: } M = \frac{n}{V}$$

$$\text{Bond Order} = (\# \text{ bonding } e^- - \# \text{ antibonding } e^-) / 2$$

$$\text{Mass solute: } m_{\text{solute}} = V \times M \times \mathcal{M}$$

$$\text{Dilution equation: } V_{\text{initial}} \times M_{\text{initial}} = V_{\text{dilute}} \times M_{\text{dilute}}$$

$$\text{Potential energy (PE): } PE = m \times g \times h$$

$$(m = \text{mass; } g = \text{acceleration due to gravity; } h = \text{vertical distance})$$

$$\text{Kinetic energy (KE): } KE = \frac{1}{2} mu^2 \text{ (} m = \text{mass; } u = \text{velocity)}$$

$$\text{Total energy} = PE + KE$$

$$\text{Electrostatic Potential Energy: } E_{el} \propto \frac{(Q_1 \times Q_2)}{d}$$

$$\text{Internal energy: } \Delta E = q + w = q - P\Delta V$$

$$\Delta H = \Delta E + P\Delta V; \quad \Delta H_{\text{rxn}} = \frac{q_{\text{rxn}}}{\text{mol rxn}}$$

$$\text{Heat capacity: } q = C \Delta T$$

$$\text{Specific heat (} c_s \text{): } q = mc_s \Delta T$$

$$\text{Molar heat capacity (} c_p \text{): } q = nc_p \Delta T$$

$$\text{Phase change: } q = n\Delta H_{\text{fus}}; q = n\Delta H_{\text{vap}}$$

$$\text{Clausius-Clapeyron Equation } \ln \left( \frac{P_2}{P_1} \right) = \frac{\Delta H_{\text{vap}}}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \text{ Gas constant: } R = 8.314 \text{ J/(mol K)} = 0.08206 \text{ atm L/(mol K)}$$

$$h = \frac{2T \cos \theta}{r \rho g} \quad g = \text{acceleration} = 9.8 \text{ m/s}^2; \rho \text{ is the density; } T = \text{surface tension; } r = \text{radius of the tube;}$$

$$\theta = \text{contact angle between the liquid and the tube.}$$

1	1	2
H	H	He
1.008	1.008	4.003
3	4	
Li	Be	
6.939	9.012	
11	12	
Na	Mg	
22.99	24.31	
19	20	
K	Ca	
39.10	40.08	
37	38	
Rb	Sr	
85.47	87.62	
55	56	
Cs	Ba	
132.9	137.3	
87	88	
Fr	Ra	
(223)	(226)	
21	22	
Sc	Ti	
44.96	47.90	
41	42	
Nb	Mo	
92.91	95.94	
73	74	
Ta	W	
180.9	183.9	
105	106	
Ha	Sg	
(268)	(271)	
43	44	
Tc	Ru	
(99)	101.1	
76	77	
Os	Ir	
190.2	192.2	
108	109	
Hs	Mt	
(270)	(276)	
45	46	
Rh	Pd	
102.9	106.4	
78	79	
Pt	Au	
195.1	197.0	
110	111	
Ds	Rg	
(281)	(280)	
47	48	
Ag	Cd	
107.9	112.4	
80	81	
Hg	Tl	
200.6	204.4	
112	113	
Cn	Uut	
(285)	(284)	
49	50	
In	Sn	
114.8	118.7	
82	83	
Pb	Bi	
207.2	209.0	
114	115	
Fl	Uup	
(289)	(288)	
51	52	
Sb	Te	
121.8	127.6	
84	85	
Po	At	
(209)	(210)	
116	117	
Lv	Uus	
(293)	(294)	
35	36	
Br	Kr	
79.91	83.80	
31	32	
Ga	Ge	
69.72	72.59	
49	50	
In	Sn	
114.8	118.7	
82	83	
Pb	Bi	
207.2	209.0	
114	115	
Fl	Uup	
(289)	(288)	
51	52	
Sb	Te	
121.8	127.6	
84	85	
Po	At	
(209)	(210)	
116	117	
Lv	Uus	
(293)	(294)	
35	36	
Br	Kr	
79.91	83.80	
31	32	
Ga	Ge	
69.72	72.59	
49	50	
In	Sn	
114.8	118.7	
82	83	
Pb	Bi	
207.2	209.0	
114	115	
Fl	Uup	
(289)	(288)	
51	52	
Sb	Te	
121.8	127.6	
84	85	
Po	At	
(209)	(210)	
116	117	
Lv	Uus	
(293)	(294)	
5	6	
B	C	
10.81	12.01	
13	14	
Al	Si	
26.98	28.09	
15	16	
P	S	
30.97	32.06	
7	8	
N	O	
14.01	16.00	
9	10	
F	Ne	
19.00	20.18	
58	59	
Ce	Pr	
140.1	140.1	
60	61	
Nd	Pm	
144.2	144.9	
62	63	
Sm	Eu	
150.4	152.0	
64	65	
Gd	Tb	
157.3	158.9	
66	67	
Dy	Ho	
162.5	164.9	
68	69	
Er	Tm	
167.3	168.9	
70	71	
Yb	Lu	
173.0	175.0	
90	91	
Th	Pa	
232.0	231	
92	93	
U	Np	
238.0	(237)	
94	95	
Pu	Am	
(244)	(243)	
96	97	
Cm	Bk	
(247)	(247)	
98	99	
Cf	Es	
(251)	(252)	
100	101	
Fm	Md	
(257)	(258)	
102	103	
No	Lw	
(259)	(262)	