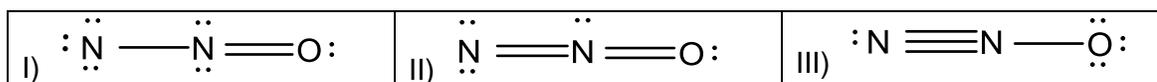


Academic Challenge  
Chemistry Test (State) – 2022

- Lead has a melting point of 328 °C and a normal boiling point of 1744 °C. In what state(s) does lead exist at 328 °C?
  - solid
  - liquid
  - gas
  - mixture of solid and liquid
  - mixture of gas and liquid
- In the list below, which formula-name is incorrect?
  - $\text{PCl}_5$  – phosphorus pentachloride
  - $\text{Fe}(\text{OH})_2$  – iron(II) hydroxide
  - $(\text{NH}_4)_2\text{CO}_3$  – ammonium carbonate
  - $\text{BaCl}_2$  – barium chloride
  - $\text{K}_2\text{S}$  – dipotassium sulfide
- The valid Lewis structure(s) for nitrous oxide,  $\text{N}_2\text{O}$ , among the following choices is (are):

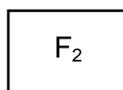


- I
  - II
  - III
  - I and II
  - II and III
- Which of the following must be true for a spontaneous endothermic process?
    - $\Delta G > 0$
    - $\Delta G = 0$
    - $\Delta H < 0$
    - $S^\circ = 0$
    - $\Delta S > 0$
  - Choose the compound that exhibits hydrogen bonding as its strongest intermolecular force.
    - $\text{CH}_3\text{OH}$
    - $\text{C}_2\text{H}_6$
    - $\text{CH}_2\text{Br}_2$
    - $\text{SBr}_2$
    - $\text{CH}_3\text{Br}$

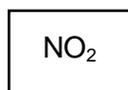
6. A 58.22 mL sample of NaOH requires 9.88 mL of 0.1775 M HCl for neutralization. What is the molar concentration of the base?
- A. 0.0301 M
  - B. 1.05 M
  - C. 0.00324 M
  - D. 0.332 M
  - E. 0.102 M

7. Consider the following three containers, with the same volume at STP, containing different gases. Which statement is correct about the number of molecules in each container?

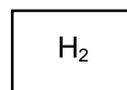
Container X



Container Y



Container Z



- A. Container X has the greatest number of molecules.
  - B. Container Y has the greatest number of molecules.
  - C. Container Z has the greatest number of molecules.
  - D. All three containers have the same number of molecules.
  - E. There is not enough information to determine the number in each.
8. Bombardment of  $^{75}\text{As}$  by deuterium,  $^2\text{H}$ , results in a proton and another isotope identified as:
- A.  $^{73}\text{Ge}$
  - B.  $^{75}\text{Ge}$
  - C.  $^{75}\text{As}$
  - D.  $^{76}\text{As}$
  - E.  $^{74}\text{Ge}$
9. Among the following, which one represents the correct chemical formula of bromous acid?
- A. HBr
  - B. HBrO
  - C. HBrO<sub>2</sub>
  - D. HBrO<sub>3</sub>
  - E. HBrO<sub>4</sub>

10. Specific heat of water is  $4.18 \text{ J/(g} \cdot ^\circ\text{C)}$ , and the specific heat of copper is  $0.382 \text{ J/(g} \cdot ^\circ\text{C)}$ . Water \_\_\_\_\_ heat compared to copper when equal masses of water and copper both initially at  $75^\circ\text{C}$  cool to  $25^\circ\text{C}$ .
- A. releases more
  - B. releases less
  - C. absorbs less
  - D. absorbs more
  - E. absorbs the same amount of
11. Which of the following would you expect to possess the highest surface tension?
- A.  $\text{CH}_3\text{CH}_2\text{OH}$
  - B.  $\text{CH}_3\text{CH}_2\text{CH}_3$
  - C.  $\text{HOCH}_2\text{CH}_2\text{OH}$
  - D.  $\text{CH}_2\text{Br}_2$
  - E.  $\text{CH}_4$
12. Select the basic anhydride among the following choices.
- A.  $\text{LiOH}$
  - B.  $\text{BaO}$
  - C.  $\text{CO}_2$
  - D.  $\text{H}_2\text{SO}_3$
  - E.  $\text{Cl}_2\text{O}_3$
13. An aqueous solution shows a pOH value of 9.85 at  $25^\circ\text{C}$ . What is the hydronium ion concentration?
- A.  $4.2 \times 10^{-10} \text{ M}$
  - B.  $7.1 \times 10^{-5} \text{ M}$
  - C.  $6.5 \times 10^{-5} \text{ M}$
  - D.  $8.7 \times 10^{-10} \text{ M}$
  - E. 9.85 M
14. A 0.100 L sample of carbon monoxide, CO, is at a pressure of 0.905 atm and a temperature of  $565^\circ\text{C}$ . What mass of CO does this represent?
- A. 0.00131 g
  - B. 0.0546 g
  - C. 21.3 g
  - D. 174 g
  - E. 0.0368 g

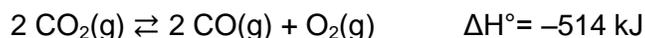
15. An electron in the  $n = 4$  level emits light with a wavelength of  $1.876 \times 10^{-6}$  m. What is the final energy level of the electron transition?

- A. 1
- B. 5
- C. 2
- D. 6
- E. 3

16. Which of the following ions is not isoelectronic with the noble gas krypton?

- A.  $\text{Rb}^+$
- B.  $\text{Br}^-$
- C.  $\text{In}^{3+}$
- D.  $\text{Sn}^{2+}$
- E.  $\text{Se}^{2-}$

17. What will be the effect of a decrease in temperature on the following equilibrium?

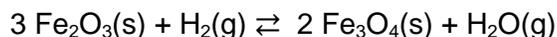


- A. The pressure of  $\text{O}_2(\text{g})$  will increase.
- B. The pressure of  $\text{CO}_2(\text{g})$  will increase.
- C. The pressure of  $\text{CO}(\text{g})$  will decrease.
- D. The value of the equilibrium constant will decrease.
- E. There will be no effect on this equilibrium.

18. How many grams of pyrazine ( $\text{C}_4\text{H}_4\text{N}_2$ ) would have to be dissolved in 2.50 kg of carbon tetrachloride to lower the freezing point by  $6.1^\circ\text{C}$ ? The freezing point depression constant for carbon tetrachloride is  $30^\circ\text{C}/\underline{\text{m}}$ .

- A. 0.51 g
- B. 41 g
- C. 78 g
- D. 0.20 g
- E. 82 g

19. When the following reaction reaches equilibrium at 303 K, the total pressure is 0.076 atm, while the partial pressure of  $\text{H}_2$  is 0.021 atm. What is the  $K_p$  for the reaction?



- A. 0.0012
- B. 3.6
- C. 2.6
- D. 0.0016
- E. 5.2

20. Which comparisons of atomic radii are incorrect?



- A. I and III
- B. II and III
- C. I and IV
- D. I and II
- E. III and IV

21. What is the ground state electron configuration of copper in CuS?

- A.  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$
- B.  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^8$
- C.  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$
- D.  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$
- E.  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9$

22. A solution is prepared by dissolving 98.6 g of NaCl in enough water to form 575 mL of solution. Calculate the mass % of water if the density of the solution is 1.06 g/mL.

- A. 19.3 %
- B. 16.2 %
- C. 83.8 %
- D. 80.7 %
- E. 74.6 %

23. A 150.0 mL sample of an aqueous solution at 25 °C contains 15.2 mg of an unknown nonelectrolyte compound. If the solution has an osmotic pressure of 8.44 torr, what is the molar mass of the unknown compound?

- A. 223 g/mol
- B. 294 g/mol
- C. 341 g/mol
- D. 448 g/mol
- E. 195 g/mol

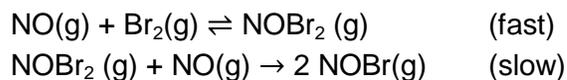
24. Which statement about the periodic table is false?

- A. Electron affinity values tend to become more negative moving left to right.
- B. Alkali metals are more reactive than Alkaline Earth metals.
- C. Metals become more reactive going down a column.
- D. Noble gases are smaller than halogens.
- E. Nonmetals become more reactive going down a column.

25. How much 0.100 M HCl would completely react with 20.0 mL of 0.0500 M calcium hydroxide?
- A. 10.0 mL
  - B. 20.0 mL
  - C. 8.00 mL
  - D. 5.00 mL
  - E. 50.0 mL
26. Choose the pair of substances that are most likely to form a homogeneous solution.
- A.  $C_6H_{14}$  and  $C_{10}H_{20}$
  - B. KCl and  $C_5H_{12}$
  - C.  $N_2O_4$  and  $NH_4I$
  - D.  $C_6H_{14}$  and  $H_2O$
  - E. None of these pairs will form a homogenous solution.
27. Which of the following is the correct order of electromagnetic radiation based on decreasing wavelength.
- A. X-ray > visible > infrared > microwave
  - B. X-ray > infrared > visible > microwave
  - C. microwave > X-ray > infrared > visible
  - D. microwave > infrared > visible > X-ray
  - E. infrared > microwave > visible > X-ray
28. A rock suspected of being gold was placed in 12.450 mL of water. The volume rose to 12.461 mL. The mass of the rock is 0.15462 g. How many digits should be reported for the density of this rock?
- A. 1
  - B. 2
  - C. 3
  - D. 4
  - E. 5
29. An analytical balance in good working order was used for a series of measurements, but later found to be not calibrated. What reasonable conclusion can be made about the values obtained?
- A. The measurements obtained are accurate but not precise.
  - B. The measurements obtained are both accurate and precise.
  - C. The measurements obtained are neither accurate nor precise.
  - D. There is no conclusion you can make about the values obtained.
  - E. The measurements obtained are precise but not accurate.

30. The mass of an electron ( $9.11 \times 10^{-31}$  kg) can be calculated from the independent findings of which two scientists?
- A. Rutherford and Thomson
  - B. Chadwick and Millikan
  - C. Thomson and Millikan
  - D. Chadwick and Thomson
  - E. Rutherford and Chadwick
31. Which whole number ratio below illustrates the Law of Multiple Proportions when comparing the mass of hydrogen in the compounds ethane ( $C_2H_6$ ) and propane ( $C_3H_8$ ) to a fixed mass of carbon?
- A. 3:4
  - B. 3:2
  - C. 1:4
  - D. 2:1
  - E. 9:8
32. The 3-element compound  $CS_2[X]_8$  is known to have a composition of 5.26% carbon and 28.11% sulfur. What is the missing element [X] in this compound?
- A. H
  - B. O
  - C. N
  - D. F
  - E. P
33. An organic compound contains 40.0% carbon, 10.1% hydrogen, 23.3% nitrogen, and 26.6% oxygen. It is known that 10.0 grams of this compound contains 0.0555 moles of molecules. What is the chemical formula for this compound?
- A.  $C_7H_{20}N_2O_3$
  - B.  $C_6H_{18}N_3O_3$
  - C.  $C_3H_9N_3O$
  - D.  $C_4H_{12}N_4O_4$
  - E.  $C_5H_{18}N_5O_2$

34. An acetate buffer with pH 4.74 is prepared with 0.200 M acetic acid and 0.200 M potassium acetate. What is the pH of 50.0 mL of this buffer after the addition of 1.50 mL of 0.500 M NaOH?
- A. 4.81  
B. 4.67  
C. 10.87  
D. 4.87  
E. 6.36
35. The  $K_{sp}$  of aluminum hydroxide is  $1.26 \times 10^{-33}$ . What is the molar solubility of this compound?
- A.  $3.55 \times 10^{-17}$  M  
B.  $5.96 \times 10^{-9}$  M  
C.  $4.21 \times 10^{-9}$  M  
D.  $2.61 \times 10^{-9}$  M  
E.  $1.49 \times 10^{-17}$  M
36. A particular experiment yields the following concentrations for reactant A, where  $t_x$  is time in x minutes: [A] at  $t_0 = 1.00$  M, [A] at  $t_{10} = 0.50$  M, [A] at  $t_{20} = 0.25$  M, [A] at  $t_{30} = 0.125$  M. Which of the following plots will yield a linear graph for this experiment?
- A.  $\ln[A]$  vs  $t$   
B.  $\frac{1}{[A]}$  vs  $t$   
C. [A] vs  $t$   
D.  $\frac{1}{\ln[A]}$  vs  $t$   
E.  $[A]^2$  vs  $t$
37. The following shows the reaction mechanism for  $\text{Br}_2(\text{g}) + 2 \text{NO}(\text{g}) \rightarrow 2 \text{NOBr}(\text{g})$ . What is the rate law for this reaction?



- A. Rate =  $k[\text{NO}][\text{Br}_2]$   
B. Rate =  $k[\text{NO}]^2[\text{Br}_2]$   
C. Rate =  $k[\text{NOBr}_2][\text{NO}_2]$   
D. Rate =  $k[\text{NO}][\text{Br}_2]^2$   
E. Rate =  $k[\text{NOBr}_2][\text{Br}_2]$

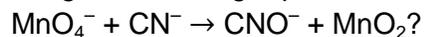
38. Which set of quantum numbers shown below is allowed for an electron?

- A.  $n = 4; \ell = 3; m_\ell = 4; m_s = \frac{1}{2}$
- B.  $n = 7; \ell = 1; m_\ell = -2; m_s = -\frac{1}{2}$
- C.  $n = 0; \ell = 0; m_\ell = 4; m_s = \frac{1}{2}$
- D.  $n = 1; \ell = 1; m_\ell = 0; m_s = -\frac{1}{2}$
- E.  $n = 6; \ell = 4; m_\ell = -4; m_s = -\frac{1}{2}$

39. In the Schrödinger equation,  $\hat{H}\psi = E\psi$ , what is the best interpretation for  $\psi$ ?

- A. Electrons are moving waves that engage in constructive interference as they move around an atom.
- B. Electrons in orbit have a fixed distance from the nuclear center.
- C. Electrons have complex probability amplitudes.
- D. Electrons can occupy any space around an atomic nucleus.
- E. Electrons have no physical reality.

40. When balancing the following equation in basic solution, what is the coefficient for  $\text{CN}^-$ :



- A. 1
- B. 2
- C. 3
- D. 4
- E. 5