Academic Challenge
Chemistry Test (State) – 2020

1. Density of a substance is a (an) _____ property.

   A. extensive
   B. intensive
   C. chemical
   D. none of these
   E. all of these

2. What is the name for $NaHSO_3$?

   A. monosodium sulfite
   B. monosodium sulfate
   C. sodium bisulfite
   D. sodium bisulfate
   E. sodium bisulfide

3. Which of the following species is expected to have resonance structure?

   A. H_2O
   B. SO_3
   C. NH_3
   D. $PC\ell_3$
   E. CH_4

4. Consider a reaction that has a negative ΔH and a negative ΔS. Which of the following statements is TRUE?

   A. This reaction will be spontaneous only at high temperatures.
   B. This reaction will be spontaneous at all temperatures.
   C. This reaction will be nonspontaneous at all temperatures.
   D. This reaction will be nonspontaneous only at high temperatures.
   E. It is not possible to determine without more information.

5. How many compounds, of the ones listed below, have hydrogen bonding?

   NH_3 $CH_3CH_2CH_2NH_2$ $CH_3CH_2NHCH_2CH_3$ $(CH_3CH_2)_2NCH_2CH_3$

   A. 0
   B. 1
   C. 2
   D. 3
   E. 4

6. What is the conjugate base of $H_2PO_4^-$?

    A. PO_4^{3-} B. HPO_4^{2-} C. H_3PO_4 D. H_3O^+ E. OH^-

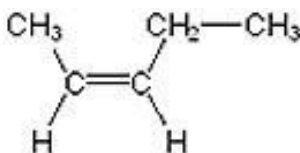7. Determine the density of CO_2 gas at STP.

    A. 5.10 g/L
    B. 4.46 g/L
    C. 3.24 g/L
    D. 2.80 g/L
    E. 1.96 g/L

8. Determine the identity of the daughter nuclide from the beta decay of $^{89}_{38}Sr$.
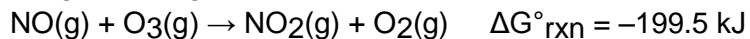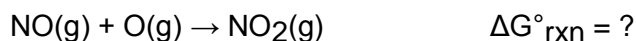
    A. $^{90}_{38}Sr$ B. $^{90}_{39}Y$ C. $^{89}_{39}Y$ D. $^{85}_{36}Kr$ E. $^{87}_{34}Se$

9. Name the following compound.

    A. cis-2-pentene
    B. trans-2-butane
    C. cis-2-butane
    D. trans-2-pentane
    E. 2- butane

10. Use Hess's law to calculate $\Delta G°_{rxn}$ using the following information.

    $NO(g) + O(g) \rightarrow NO_2(g)$ $\Delta G°_{rxn} = ?$

    $2\ O_3(g) \rightarrow 3\ O_2(g)$ $\Delta G°_{rxn} = +489.6$ kJ
    $O_2(g) \rightarrow 2\ O(g)$ $\Delta G°_{rxn} = +463.4$ kJ
    $NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$ $\Delta G°_{rxn} = -199.5$ kJ

    A. +753.5 kJ
    B. +277.0 kJ
    C. -676.0 kJ
    D. -1152.5 kJ
    E. -225.7 kJ

11. Identify the place which has the highest boiling point of water.

   A. New Orleans, sea level
   B. Mt. Everest, 29035 feet
   C. Denver, Colorado, 5280 feet
   D. a pressurized passenger jet, 35,000 feet
   E. Death Valley, 282 feet below sea level

12. Which of the following solutions would have the highest pH? Assume that they are all 0.10 M in acid at 25 °C. The acid is followed by its K_a value.

   A. HCN, 4.9×10^{-10}
   B. HF, 3.5×10^{-4}
   C. HNO_2, 4.6×10^{-4}
   D. $HCHO_2$, 1.8×10^{-4}
   E. $HC\ell O_2$, 1.1×10^{-2}

13. If 2.0 mol of gas A is mixed with 1.0 mol of gas B to give a total pressure of 1.6 atm, what is the partial pressure of gas A and B?

   A. $P_A = 0.33$ atm and $P_B = 0.67$ atm
   B. $P_A = 0.67$ atm and $P_B = 0.33$ atm
   C. $P_A = 1.0$ atm and $P_B = 2.0$ atm
   D. $P_A = 2.0$ atm and $P_B = 1.0$ atm
   E. $P_A = 1.06$ atm and $P_B = 0.53$ atm

14. Calculate the hydronium ion concentration in an aqueous solution with a pOH of 9.85 at 25 °C.

   A. 7.1×10^{-5} M
   B. 4.2×10^{-10} M
   C. 8.7×10^{-10} M
   D. 6.5×10^{-5} M
   E. 1.4×10^{-10} M

15. An aqueous solution of a nonelectrolyte has a normal boiling point of 103.0 ^{0} C. What is the freezing point of this solution? For water, $k_b = 0.51$ ^{0} C/m and $k_f = 1.86$ ^{0} C/m.

   A. -0.82 ^{0} C
   B. -3.6 ^{0} C
   C. -3.0 ^{0} C
   D. -11 ^{0} C
   E. 0.0 ^{0} C

16. Which ground-state electron configuration is possible for an atom in the second period?

    A. $1s^2 2s^1 2p^1$
    B. $1s^2 2s^2 2d^1$
    C. $1s^2 2s^2 2p^6 2d^1$
    D. $1s^2 2s^2 2p^7$
    E. $1s^2 2s^1$

17. Chemiluminescence of which of the following colors corresponds to electromagnetic radiation with the highest frequency?

    A. red   B. yellow   C. blue   D. orange   E. green

18. Solution X boils at 100.26 ^{0} C and solution Y boils at 101.04 ^{0} C. Both solutions are at atmospheric pressure and contain the same solute concentration. Which of the following conclusions can be drawn?

    A. The freezing point of solution X is lower than that of solution Y.
    B. The vapor pressure of solution X is higher than that of solution Y.
    C. Solution X and solution Y are immiscible.
    D. The vapor pressure of solution X is lower than that of solution Y at 100.26 ^{0} C.
    E. The osmotic pressure of solution X is higher than that of solution Y.

19. When an electron falls from $n = 3$ to $n = 2$ in a hydrogen atom, what is the value of the energy released, given that A is the energy needed to remove an electron from the ground state of a hydrogen atom to an infinite distance from the atom?

    A. $0.14A$
    B. $0.17A$
    C. $1.00A$
    D. $5.00A$
    E. $0.083A$

20. Which of the following statements is generally true?

    A. The solubility of a solid is not dependent on either temperature or pressure.
    B. The solubility of a solid is highly dependent on pressure.
    C. The solubility of a solid is highly dependent on temperature.
    D. The solubility of a solid is highly dependent on both pressure and temperature.
    E. None of the above.

21. Which species has this ground state electron configuration?

$$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$$
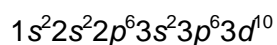
   A. Zn^{2+}
   B. Ga^{3+}
   C. Cu^+
   D. all of these cations
   E. none of these cations

22. The combustion of C_3H_8O with O_2 is represented by this balanced chemical equation.

$$2\ C_3H_8O\ +\ 9\ O_2\ \rightarrow\ 6\ CO_2\ +\ 8\ H_2O$$
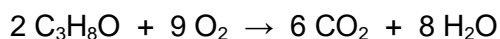
When 3.00 g of C_3H_8O and 7.38 g of O_2 are combined, how many moles of which reagent remain?

   A. 0.006 mol O_2
   B. 0.024 mol C_3H_8O
   C. 0.24 mol O_2
   D. 0.18 mol C_3H_8O
   E. Neither reactant will remain upon completion.

23. The first three ionization energies of an element **X** are 590, 1145, and 4912 kJ/mol. What is the most likely formula a stable ionic chloride formed using element **X**.
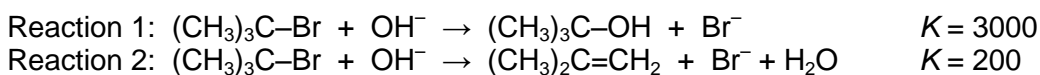
   A. $XC\ell$
   B. $XC\ell_2$
   C. $X_3C\ell_2$
   D. $XC\ell_3$
   E. $XC\ell_4$

24. What is the mole fraction of water in 200 g of 95% (by mass) ethanol (C_2H_6O)?

   A. 0.050
   B. 0.12
   C. 0.56
   D. 0.88
   E. 0.13

The following **two** questions both pertain to the two reactions shown below.

25. When $(CH_3)_3C-Br$ is exposed to sodium hydroxide, the following two reactions occur.

 Reaction 1: $(CH_3)_3C-Br + OH^- \rightarrow (CH_3)_3C-OH + Br^-$ $K = 3000$
 Reaction 2: $(CH_3)_3C-Br + OH^- \rightarrow (CH_3)_2C=CH_2 + Br^- + H_2O$ $K = 200$

 For <u>reaction 2</u>, what could be done to shift the equilibrium to the right, favoring the formation of the C=C?

 A. Add excess water to the reaction mixture.
 B. Use $(CH_3)_3C-C\ell$ as the starting material instead of $(CH_3)_3C-Br$.
 C. Add $AgNO_3$ to precipitate out the bromide ions.
 D. Use a lower concentration of hydroxide ions.
 E. Add a catalyst.

26. Which of the following statements is true concerning the two reactions?

 A. Increasing the temperature would not affect either reaction.
 B. The equilibrium concentrations of the two products would be equal.
 C. The amount of $(CH_3)_3C-OH$ present at equilibrium will be less than the amount of $(CH_3)_2C=CH_2$ present at equilibrium.
 D. The amount of $(CH_3)_3C-OH$ present at equilibrium will be greater than the amount of $(CH_3)_2C=CH_2$ present at equilibrium.
 E. Reaction 2 has a higher activation energy.

27. Oxygen has a lower ionization energy than nitrogen, despite being further to the right on the periodic table. What is the best way to explain this observation?

 A. It is easier to add electrons to oxygen than it is to nitrogen because oxygen is the more electronegative element.
 B. Oxygen loses an electron from a $2p$ sublevel, while nitrogen loses an electron from a $2s$ sublevel.
 C. Oxygen has an even number of electrons, thereby making it easier to remove an electron.
 D. Removing an electron from nitrogen results in a half-filled p-sublevel making it more difficult to remove.
 E. The first electron removed from oxygen is a paired $2p$ electron, which is easier to remove compared to one of the three unpaired $2p$ electrons in nitrogen.

28. The fictional Wilson temperature scale works like this: each unit is 5.0 times as big as a Kelvin unit (i.e. 1 °W change is equal to 5 K change) and 0 on the Wilson scale corresponds to the boiling point of water. Convert –35 °W to Kelvin.

 A. 408 K
 B. 338 K
 C. 238 K
 D. 198 K
 E. 98 K

29. What is the minimum number of steps required to convert feet to meters using only common and exact conversion factors?

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

30. How many covalent bonds total would be found in 1 formula unit of ammonium phosphate?

    A. 2   B. 8   C. 9   D. 16   E. 17

31. Given 2.8 g of nitrogen, how many grams of oxygen would be needed to make dinitrogen pentoxide, assuming 100% product yield with no leftover reactants?

    A. 1.6 g
    B. 4.8 g
    C. 7.0 g
    D. 8.0 g
    E. 14.0 g

32. Given a 20.0 g sample of calcium nitrite, what percent of its mass is due to nitrogen?

    A. 21.2%
    B. 16.3%
    C. 27.5%
    D. 17.1%
    E. 10.6%

33. A compound with a molar mass of 294.30 g/mol has the following mass percent's: 57.14% C, 6.16% H, 9.52% N, and 27.18% O. What is the molecular formula for this compound?

    A. $C_4H_6NO_2$
    B. $C_6H_{12}NO_6$
    C. $C_{28}H_{36}N_4O_{10}$
    D. $C_{14}H_{18}N_2O_5$
    E. $C_7H_9NO_2$

34. Given a molar solubility for nickel(II) hydroxide of 5.2×10^{-6} M, calculate its K_{sp} value in water.

    A. 5.2×10^{-16}
    B. 5.2×10^{-6}
    C. 2.7×10^{-11}
    D. 1.4×10^{-16}
    E. 5.6×10^{-16}

35. What is the pH of the buffer formed by adding 50.0 mL of 0.500 M KOH to 200.0 mL of 0.500 M propanoic acid (CH_3CH_2COOH)? The K_a of propanoic acid is 1.34×10^{-5}.

   A. 4.39
   B. 4.87
   C. 5.35
   D. 8.65
   E. 9.60

36. What is the rate law for the following hypothetical reaction mechanism?

$$B \rightarrow C + E \quad \text{(slow)}$$
$$A + E \rightarrow F \quad \text{(fast)}$$
$$A + F \rightarrow D \quad \text{(fast)}$$
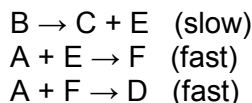
   A. rate = k[B]
   B. rate = k[C][E]
   C. rate = k[A][E]
   D. rate = k[A]^2
   E. rate = k[A]^2[B]

37. According to collision theory, which of the following would you NOT expect to increase the rate of the reaction $2 A + B \rightarrow 2 C + D$?

   A. increasing the concentration of A
   B. increasing the temperature of the reaction by 5 Kelvin
   C. using a catalyst to orient reactants for more effective collisions
   D. crushing any solid reactants instead of using a solid block of that material
   E. increasing the concentration of C

38. The highest frequency ultraviolet light emitted by an atom after excitation with a laser would most likely be caused by an electron moving through which of these transitions?

   A. shell 1 → shell 2
   B. shell 4 → shell 1
   C. shell 2 → shell 1
   D. shell 8 → shell 5
   E. shell 1 → shell 4

39. How many total electrons in the element cesium (Cs – atomic number 55) are occupying d-orbitals?

   A. 10
   B. 20
   C. 21
   D. 24
   E. 57

40. The Nernst equation, shown below, can be used to find cell potentials when there are nonstandard conditions. If the reaction quotient is less than 1, what effect would this have on the value of E relative to E^o?

$$E = E^o - \frac{RT}{nF}\ln Q$$

A. It's impossible to say without knowing the exact value of Q.
B. It's impossible to say without knowing the exact value of E^o.
C. E would be higher than E^o.
D. E would be lower than E^o.
E. E would be the same as E^o.