2023 Academic Challenge

STATE CHEMISTRY EXAM

Chemistry Test Production Team

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GENERAL DIRECTIONS

Please read the following instructions carefully. This is a timed test; any instructions from the test supervisor should be followed promptly.

The test supervisor will give instructions for filling in any necessary information on the answer sheet. Most Academic Challenge sites will ask you to indicate your answer to each question by marking an oval that corresponds to the correct answer for that question. One oval should be marked to answer each question. Multiple ovals will automatically be graded as an incorrect answer.

Be sure ovals are marked as ● , not ⊙ , ◫ , ◑ , etc.

If you wish to change an answer, erase your first mark completely before marking your new choice.

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not waste your time on questions that seem too difficult for you. Go on to the other questions, and then come back to the difficult ones later if time remains.

Time: 40 Minutes Number of Questions: 40

DO NOT OPEN TEST BOOKLET UNTIL YOU ARE TOLD TO DO SO!

Periodic Table of the Elements

1 IA																	17 VIIA	18 VIIIA
1 **H** 1.0079	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA		1 **H** 1.0079	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999		9 **F** 18.998	10 **Ne** 20.179
11 **Na** 22.990	12 **Mg** 24.305	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 ←	9 VIIIB	10 →	11 IB	12 IIB	13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.06		17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.08	21 **Sc** 44.956	22 **Ti** 47.90	23 **V** 50.941	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.70	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.922	34 **Se** 78.96		35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.22	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** [97.91]	44 **Ru** 101.07	45 **Rh** 102.905	46 **Pd** 106.4	47 **Ag** 107.868	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60		53 **I** 126.904	54 **Xe** 131.30
55 **Cs** 132.905	56 **Ba** 137.33	57-71 **La**	72 **Hf** 178.49	73 **Ta** 180.948	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.05	79 **Au** 196.966	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** [208.98]		85 **At** [209.99]	86 **Rn** [222.02]
87 **Fr** [223.02]	88 **Ra** [226.03]	89-103 **Ac**	104 **Rf** [265.12]	105 **Db** [268.13]	106 **Sg** [271.13]	107 **Bh** [270]	108 **Hs** [277.15]	109 **Mt** [276.15]	110 **Ds** [281.16]	111 **Rg** [280.16]	112 **Cn** [285.17]	113 **Nh** [284.18]	114 **Fl** [289.19]	115 **Mc** [288.19]	116 **Lv** [293]		117 **Ts** [294]	118 **Og** [294]

Lanthanides	57 **La** 138.905	58 **Ce** 140.12	59 **Pr** 140.907	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.4	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 164.930	68 **Er** 167.26	69 **Tm** 168.934	70 **Yb** 173.04	71 **Lu** 174.967
Actinides	89 **Ac** [277.03]	90 **Th** 232.038	91 **Pa** 231.035	92 **U** 238.029	93 **Np** [237.05]	94 **Pu** [244.06]	95 **Am** [243.06]	96 **Cm** [247.07]	97 **Bk** [247.07]	98 **Cf** [251.08]	99 **Es** [252.08]	100 **Fm** [257.10]	101 **Md** [258.10]	102 **No** [259.10]	103 **Lr** [262.11]

$q = m \cdot c_s \cdot \Delta T$

$\Delta T_b = i \cdot K_b \cdot m$

$\mathrm{P_{solvent}} = \mathrm{X_{solvent}} \cdot \mathrm{P^o_{solvent}}$

$\ln\left(\frac{[A]_t}{[A]_0}\right) = -kt$

$[A]_t - [A]_0 = -kt$

$\mathrm{pH} = -\log[\mathrm{H_3O^+}]$

$\mathrm{pH} = \mathrm{pK}_a + \log\left(\frac{[A^-]}{[HA]}\right)$

$\Delta G^0 = \Delta H^0 - T\Delta S^0$

$\Delta E = B\left(\frac{1}{n_f^2 - n_i^2}\right)$

$\Delta G^0 = -nF\varepsilon^0$

$\Pi = MRT$

$F = 96485\ \frac{\mathrm{C}}{\mathrm{mol}}$

$R = 0.08206\ \frac{\mathrm{L \cdot atm}}{\mathrm{mol \cdot K}}$

$1.0\ \mathrm{kg} = 2.2\ \mathrm{lb}$

$1.0\ \mathrm{in} = 2.54\ \mathrm{cm}$

$1\ \mathrm{lb} = 453.59\ \mathrm{g}$

$c = 2.998 \times 10^8\ \mathrm{m/s}$

$h = 6.626 \times 10^{-34}\ \mathrm{J \cdot s}$

$\Delta T_f = i \cdot K_f \cdot m$

$S_{gas} = k_H \cdot P_{gas}$

$k = Ae^{-E_a/RT}$

$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$

$\ln\left(\frac{k_2}{k_1}\right) = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$\mathrm{pOH} = -\log[\mathrm{OH^-}]$

$\Delta S_{surr} = \frac{-\Delta H_{sys}}{T}$

$E_{cell}^\circ = E_{red}^\circ + E_{ox}^\circ$

$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$c = \lambda\upsilon$

$\Delta E = h\upsilon$

$K_w = 1.0 \times 10^{-14}$

$B = -2.18 \times 10^{-18}\ \mathrm{J}$

$N_A = 6.022 \times\ 10^{23}$

$1\ \mathrm{atm} = 101{,}325\ \mathrm{Pa} = 1.01325\ \mathrm{bar}$

$1\ \mathrm{J} = 1\ \mathrm{N \cdot m} = 1\ \mathrm{kg \cdot m \cdot s^2} = 0.239\ \mathrm{cal}$

Assume all gases behave ideally unless specifically told to do otherwise

Assume all solutions are aqueous and at 25 °C unless specifically told otherwise
Assume all gases are at STP unless specifically told otherwise

Simple Rules for the Solubility of Salts in Water

1. Most nitrates are soluble
2. Most salts containing Group 1 ions or ammonium (NH_4^+) are soluble
3. Most chloride, bromide, and iodide salts are soluble except those of Ag^+, Pb^{2+}, and Hg_2^{2+}.
4. Most sulfates are soluble with the exception of Ba^{2+}, Pb^{2+}, Hg_2^{2+}, and Ca^{2+}
5. Most hydroxide salts are only slightly soluble with the exception of Group 1 hydroxides. Group 2 (Ba^{2+} to Ca^{2+}) are slightly soluble.
6. Most sulfides, carbonates, chromates, and phosphates are only slightly soluble

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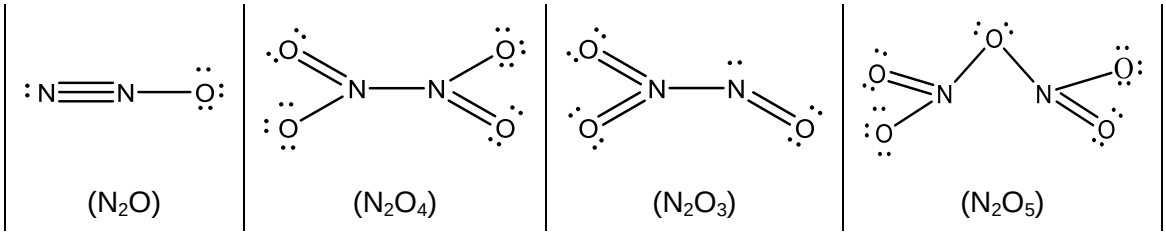
1. Which of the following method is the best for the separation of a mixture of ethyl alcohol and water?

   A. distillation
   B. light absorption
   C. electrolysis
   D. gas-liquid chromatography
   E. filtration

2. What is the correct name for $TiC\ell_4$?

   A. monotitanium tetrachloride
   B. tetrachlorine titanate
   C. titanium tetrachlorine
   D. titanium(IV) tetrachloride
   E. titanium(IV) chloride

3. All of the following Lewis structures of nitrogen oxides are possible EXCEPT



   A. N_2O
   B. N_2O_4
   C. N_2O_3
   D. N_2O_5
   E. All of the above are correct structures.

4. Use the following thermochemical information

   (1) $S_8(s) + 8\ O_2(g) \rightarrow 8\ SO_2(g)$ $\quad \Delta H_1 = -2374.6$ kJ
   (2) $S_8(s) + 12\ O_2(g) \rightarrow 8\ SO_3(g)$ $\quad \Delta H_2 = -3165.8$ kJ

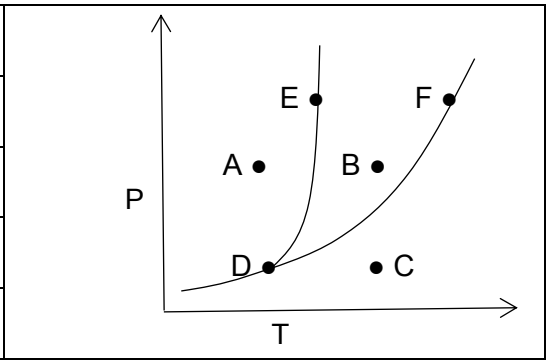
   to calculate the ΔH_{rxn} for the combustion of sulfur dioxide

   $$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$$

   A. –5540 kJ
   B. –1385.1 kJ
   C. –197.8 kJ
   D. 251.7 kJ
   E. 791.2 kJ

5. On the phase diagram (right side of the table), which point corresponds to conditions where solid, liquid, and gas phases all exist in equilibrium?

A.	A
B.	B
C.	C
D.	D
E.	E



6. A salt solution can be acidic, basic, or neutral. When dissolved in water, which of the following salts will make the solution basic?

$FeC\ell_3$, NaBr, $CaCO_3$, Na_3PO_4, NH_4Br

A. $CaCO_3$ and Na_3PO_4
B. $FeC\ell_3$ and NaBr
C. $FeC\ell_3$ and $CaCO_3$
D. Na_3PO_4 and NH_4Br
E. NH_4Br

7. All of the following relationships are false EXCEPT

A. Volume is inversely proportional to the moles of gas.
B. Volume is directly proportional to pressure in mmHg.
C. Volume is directly proportional to pressure in atmospheres.
D. Volume is directly proportional to temperature in Kelvin.
E. Volume is directly proportional to the gas constant R.

8. Beta (β) particles have the identical properties of

A. helium atoms that have been stripped of their electrons.
B. elemental helium.
C. high energy radiation.
D. neutrons.
E. electrons.

9. Which of the following compounds is an alkane?

A. C_3H_6
B. C_3H_4
C. C_2H_6
D. C_2H_4
E. C_2H_2

10. When ammonium nitrate dissolves spontaneously in water the temperature of the solution decreases. Which statement is true for the system?

    A. $\Delta H < 0$ and $\Delta S < 0$
    B. $\Delta H < 0$ and $\Delta S = 0$
    C. $\Delta H = 0$ and $\Delta S > 0$
    D. $\Delta H > 0$ and $\Delta S > 0$
    E. $\Delta H > 0$ and $\Delta S < 0$

11. Among the H_2X molecules (e.g., H_2O, H_2S, H_2Se, H_2Te), water has the highest melting point due to the fact that it possess a significant amount of

    A. London force.
    B. dipole-diploe interaction.
    C. ion-dipole interaction.
    D. dipole-induced dipole.
    E. hydrogen bonding.

12. The conjugate acid of a weak base is

    A. amphiprotic.
    B. a weak base.
    C. a weak acid.
    D. a strong acid.
    E. a strong base.

13. If 6.00 g nitrogen gas (N_2) is introduced into an evacuated 2.00 L steel flask at 27 ^{o}C, what is the pressure inside the flask?

    A. 2.64 atm
    B. 0.246 atm
    C. 1.83 atm
    D. 15.8 atm
    E. 74.1 atm

14. The pH of a human blood sample is found to be 7.3. What is the concentration of OH^- ion in this blood?

    A. 5.01×10^{-8} M
    B. 2.0×10^{-7} M
    C. 7.3×10^{-7} M
    D. 5.01×10^{-5} M
    E. 2.0×10^{7} M

15. Which one of the following is not a valid value for the magnetic quantum number of an electron in a 5*d* subshell?

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

16. Calculate the longest wavelength of light (nm) that can be used to remove electrons from metal surfaces if 245 kJ/mol is required to eject electrons.

    A. 725
    B. 233
    C. 165
    D. 488
    E. 552

17. A 0.205 *M* aqueous solution of some unknown had an osmotic pressure of 7874 mmHg at 35 ^{0} C. Which one of the following could be the unknown compound?

    A. $CaBr_2$
    B. $NaC\ell$
    C. CH_3OH
    D. Na_2CO_3
    E. $C_6H_{12}O_6$

18. A particular first-order reaction has a rate constant of 1.35 x 10^2 s^{-1} at 25 ^{0} C. What is the magnitude of *k* at 65.0 ^{0} C if E_a = 55.5 kJ/mol?

    A. 1.95 x 10^4 s^{-1}
    B. 358 s^{-1}
    C. 3.48 x 10^{73} s^{-1}
    D. 1.92 x 10^3 s^{-1}
    E. 1.35 x 10^2 s^{-1}

19. A water sample tested positive for lead with a concentration of 35 ppm. The density of the solution is 1.00 g/mL. Which of the following statements is correct?

    A. The solution is 35% by mass of lead.
    B. The molarity of the solution is 35 M.
    C. 100 g of the solution contains 35 mg of lead.
    D. There are 35 mg of lead in 1.0 L of this solution.
    E. 100 g of the solution contains 35 g of lead.

20. How many grams of Ca metal are produced by the electrolysis of molten $CaBr_2$ using a current of 30.0 A for 8.0 hours? (Useful information: 1 mole e^- = 9.6485 x 10^4 C)

A. 0.0622
B. 17.9
C. 359
D. 89.7
E. 179

21. Given the following proposed mechanism, predict the rate law for the overall reaction.

Mechanism:

$2\ NO(g) \rightleftharpoons N_2O_2(g)$ fast
$H_2(g) + N_2O_2(g) \rightarrow H_2O(g) + N_2O(g)$ slow
$H_2(g) + N_2O(g) \rightarrow H_2O(g) + N_2(g)$ fast

A. rate = $k[NO]^2[H_2]$
B. rate = $k[NO]^2[H_2]^2$
C. rate = $k[NO]^2$
D. rate = $k[H_2][N_2O_2]$
E. rate = $k[NO]^2[H_2]^2[N_2O_2][N_2O]$

22. In the generation of most anions, the energy change (kJ/mol) that _____ an electron is _____.

A. adds, positive
B. adds, negative
C. removes, positive
D. removes, negative
E. None of the above is correct.

23. A mixture containing 33.0 g of an unknown nonelectrolyte and 230.0 g of water has a freezing point of –1.12 ^{0} C. Given k_f = 1.86 ^{0} C/*m* for water, what is the molar mass of the unknown liquid?

A. 0.602 g/mol
B. 239 g/mol
C. 54.8 g/mol
D. 143 g/mol
E. 138 g/mol

24. How many unpaired electrons are in the ground state of a selenium atom?

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

25. Which of the following will not be observed when electrons act as waves?

A. destructive interference
B. diffraction
C. exact position
D. velocity
E. constructive interference

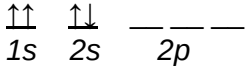
26. A buffer is prepared by dissolving 0.350 mol of acid in 1.00 L of 1.10 M conjugate base. The pH of the solution was then found to be 11.23. Determine the K_b of the conjugate base. (Assume the final volume is 1.00 L).

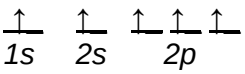
A. 4.37×10^{-4}
B. 1.46×10^{-13}
C. 1.86×10^{-12}
D. 5.25×10^{-3}
E. 5.37×10^{-4}

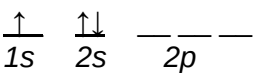
27. Sulfur, S(s), and fluorine gas react to produce gaseous sulfur hexafluoride. When a 4.50 g sample of fluorine is used, the experiment results in an 83.1% yield. How much sulfur hexafluoride was produced?

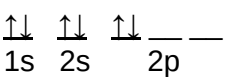
A. 14.4 g
B. 9.58 g
C. 4.79 g
D. 3.74 g
E. 43.1 g

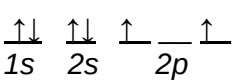
28. Which orbital diagram represents a violation of the Pauli Exclusion Principle?

A. 

B. 

C. 

D. 

E. 

29. Of the following, _____ radiation has the lowest wavelength and _____ radiation has the greatest energy.

gamma ultraviolet visible

A. visible, gamma
B. ultraviolet, gamma
C. gamma, visible
D. gamma, gamma
E. visible, ultraviolet

30. At 400 K, the equilibrium constant, K_p, for the reaction below is 7.0.

$$Br_2(g) + C\ell_2(g) \rightleftharpoons 2\ BrC\ell(g)$$

A closed vessel at 400 K is charged with 1.00 atm of $Br_2(g)$, 1.00 atm of $C\ell_2(g)$, and 2.00 atm of $BrC\ell(g)$. Which of the statements below is true?

A. The equilibrium partial pressure of $BrC\ell$ will be greater than 2.00 atm.
B. The reaction will go to completion since there are equal amounts of Br_2 and $C\ell_2$.
C. The equilibrium partial pressures of the three gases will be the same as the initial values.
D. At equilibrium, the total pressure in the vessel will be less than the initial total pressure.
E. The equilibrium partial pressure of Br_2 will be greater than 1.00 atm.

31. What is the molality of $LiC\ell$ in a solution that is 9.0 % by mass $LiC\ell$ and has a density of 1.00 g/mL?

A. 2.12 *m*
B. 9.00 *m*
C. 2.33 *m*
D. 90.0 *m*
E. 0.0900 *m*

32. What is the molar solubility of $PbC\ell_2$ in a 0.15 M solution of $HC\ell$? The value of K*sp* for $PbC\ell_2$ is 1.6×10^{-5}.

A. 1.8×10^{-4} M
B. 1.6×10^{-5} M
C. 1.1×10^{-4} M
D. 2.0×10^{-3} M
E. 7.1×10^{-4} M

33. Which is the electron configuration belonging to the atom with the highest second ionization energy?

A. $1s^2 2s^2 2p^6 3s^1$
B. $1s^2 2s^2 2p^6 3s^2$
C. $1s^2 2s^2 2p^6 3s^2 3p^1$
D. $1s^2 2s^2 2p^6 3s^2 3p^4$
E. $1s^2 2s^2 2p^6 3s^2 3p^5$

34. The equilibrium constant expression depends on which of the following?

A. mechanism
B. stoichiometry
C. the quantities of reactants and products initially present
D. the amount of gaseous reactants present at equilibrium
E. stoichiometry and mechanism

35. All of the following relationships are false EXCEPT

A. 1.5 cm^3 = 1.5 mL
B. 3.00 m^3 < 3.00 L
C. 5.2 m^3 = 5.2 x 10^2 cm^3
D. 0.0455 L > 455 mL
E. 22 L = 22 km^3

36. Identify the ions and their charges in KH_2PO_4.

A. K^+, H^+, P^{3-}, O^{2-}
B. K^+, H^{2+}, P^{3-}, O^{8-}
C. K^+, H_2^{2+}, P^-, O_4^{2-}
D. K^+, H^{2+}, PO^{3-}
E. K^+, $H_2PO_4^-$

37. A compound is found to contain 60.06% Si and 39.94% N by mass. What is its empirical formula?

A. Si_3N_2
B. Si_3N_4
C. Si_3N_3
D. Si_4N_4
E. Si_2N_3

38. How many ounces are contained in a 2.0 L soft drink bottle? (1.00 ounce = 29.6 mL)

A. 0.017 oz
B. 68 oz
C. 0.068 oz
D. 59 oz
E. 1.4 x 10^2 oz

39. Which two atoms below have the same number of neutrons?

$$^{15}_{8}\mathrm{O},\quad ^{16}_{8}\mathrm{O},\quad ^{20}_{9}\mathrm{F},\quad ^{20}_{10}\mathrm{Ne},\quad ^{22}_{11}\mathrm{Na}$$

A. $^{15}_{8}\mathrm{O}$ and $^{16}_{8}\mathrm{O}$

B. $^{16}_{8}\mathrm{O}$ and $^{22}_{11}\mathrm{Na}$

C. $^{20}_{9}\mathrm{F}$ and $^{20}_{10}\mathrm{Ne}$

D. $^{20}_{9}\mathrm{F}$ and $^{22}_{11}\mathrm{Na}$

E. $^{20}_{10}\mathrm{Ne}$ and $^{22}_{11}\mathrm{Na}$

40. Combustion analysis of a hydrocarbon produced 33.01 g CO_2 and 13.51 g H_2O. What is the empirical formula of this hydrocarbon?

A. CH_4
B. CH_2
C. C_2H_5
D. C_2H_2
E. CH_3