Academic Challenge

EASTERN ILLINOIS UNIVERSITY

2019 Academic Challenge

CHEMISTRY TEST – STATE

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

1A	2A											3A	4A	5A	6A	7A	8A
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La* 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226	89 Ac** (227)	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une									

*Lanthanides	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
**Actinides	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

Potentially Useful Information

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

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

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

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

$P_{solvent} = X_{solvent} \bullet P°_{solvent}$

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

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

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

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

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

$\ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta H_{rxn}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

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

$pH = -\log [H_3O^+]$

$pOH = -\log [OH^-]$

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

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

$\Delta G° = \Delta H° - T\Delta S°$

$E_{cell}° = E_{red}° + E_{ox}°$

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

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

$\Delta G° = -nF\varepsilon°$

$c = \lambda\nu$

$\Pi = MRT$

$\Delta E = h\nu$

$F = 96485$ C/mol

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

$R = 0.08206$ L atm/mol K; 8.3145 J/mol K

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

1.0 kg = 2.2 lb

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

1.0 in = 2.54 cm

1 atm = 101,325 Pa = 1.01325 bar

1 lb = 453.59 g

1 J = 1 N • m = 1 kg • m^2 • s^{-2} = 0.239 cal

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

$h = 6.626 \times 10^{-34}$ J·s

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.

Academic Challenge

2019 State Chemistry Exam

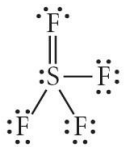
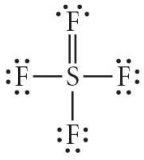
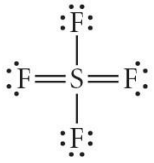
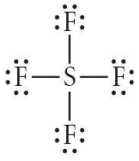
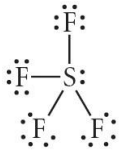
1. Determine the identity of the daughter nuclide from the alpha decay of $^{222}_{86}\mathrm{Rn}$.

   A. $^{226}_{88}\mathrm{Ra}$ B. $^{218}_{84}\mathrm{Po}$ C. $^{224}_{90}\mathrm{Th}$ D. $^{223}_{86}\mathrm{Rn}$ E. $^{221}_{85}\mathrm{At}$

2. When two solutions are added together, the new solution becomes hot. This means that

   A. a gas is being produced.
   B. the solutions are not soluble.
   C. the physical properties are the same.
   D. a chemical change is taking place.
   E. Nothing is happening.

3. Select the best Lewis structure for SF_4.

   A.  B.  C.  D.  E. 

4. Which of the following is the correct name for $CoC\ell_2 \cdot 6H_2O$?

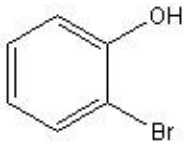
   A. cobalt chloride hydrate
   B. cobalt(I) chloride heptahydrate
   C. cobalt(II) chloride heptahydrate
   D. cobalt(II) chloride hexahydrate
   E. cobalt(I) chloride

5. Above what temperature does the following reaction become nonspontaneous?

   $$FeO(s) + CO(g) \rightarrow CO_2(g) + Fe(s) \qquad \Delta H = -11.0\ kJ;\ \Delta S = -17.4\ J/K$$

   A. 298 K
   B. 191 K
   C. 632 K
   D. This reaction is nonspontaneous at all temperatures.
   E. This reaction is spontaneous at all temperatures.

6. Name the following compound.



A. 2-bromophenol
B. 2-bromoaniline
C. 2-bromonaphthalene
D. 2-bromotoluene
E. 2-bromoanisole

7. In a liquid, the energy required to increase the surface area by a unit amount is called

A. surface tension.
B. viscosity.
C. dipole-dipole force.
D. hydrogen bonding.
E. capillary action.

8. What is the K_W of pure water at 50.0 °C, if the pH is 6.630?

A. 2.34×10^{-7}
B. 2.13×10^{-14}
C. 5.50×10^{-14}
D. 1.00×10^{-14}
E. There is not enough information to calculate the K_W.

9. How much energy is **evolved** during the formation of 98.7 g of Fe, according to the reaction below?

$$Fe_2O_3(s) + 2\ A\ell(s) \rightarrow A\ell_2O_3(s) + 2\ Fe(s) \qquad \Delta H^\circ_{rxn} = -852\ kJ$$

A. 754 kJ
B. 1.51×10^3 kJ
C. 4.20×10^3 kJ
D. 482 kJ
E. 241 kJ

10. Which of the following must be overcome during the boiling of acetonitrile, CH_3CN?

1. dispersion forces 2. dipole-dipole forces 3. hydrogen bonds

A. 1 only B. 2 only C. 1 and 2 D. 1 and 3 E. 1, 2, and 3

11. Determine the K_a of an acid whose 0.294 M solution has a pH of 2.80.

A. 1.2×10^{-5}
B. 8.6×10^{-6}
C. 2.7×10^{0}
D. 4.9×10^{-7}
E. 5.4×10^{-3}

12. Determine the volume of H_2S (at 375 K and 1.20 atm) needed to produce 55.0 g of S. Assume that there is excess SO_2 present.

$$2\ H_2S(g) + SO_2(g) \rightarrow 3\ S(s) + 2\ H_2O(g)$$

A. 44.0 L
B. 29.3 L
C. 22.7 L
D. 34.1 L
E. 66.0 L

13. A solution with a hydroxide ion concentration of 4.15×10^{-6} M is _____ and has a hydrogen ion concentration of _____.

A. acidic, 2.41×10^{-8} M
B. acidic, 2.41×10^{-9} M
C. basic, 2.41×10^{-8} M
D. basic, 2.41×10^{-9} M
E. neutral, 1.00×10^{-7} M

14. Which of the following samples has the greatest density at STP?

A. NO_2
B. Xe
C. SO_2
D. CO_2
E. SF_6

15. A 4.369 g sample of metal is placed in a flask. Water is added to the flask and the total volume in the flask is found to be 126.4 mL. The mass of the water, flask, and metal is 268.5 g. If the mass of the flask is 139.3 g and the density of water is 1.000 g/mL, the density of the solid is _____ g/cm^3.

    A. 2.78
    B. 0.366
    C. 1.56
    D. 0.641
    E. 3.21

16. Aluminum reacts with a certain nonmetallic element to form a compound with the general formula AℓX. Element X is a diatomic gas at room temperature. Element X must be _____.

    A. nitrogen
    B. oxygen
    C. fluorine
    D. chlorine
    E. sulfur

17. Combustion of a 0.600 g sample of a compound containing only carbon, hydrogen, and oxygen produced 1.043 g of CO_2 and 0.567 g of H_2O. What is the empirical formula of the compound?

    A. C_2H_5O
    B. $C_2H_5O_2$
    C. **$C_3H_8O_2$**
    D. $C_3H_8O_2$
    E. C_2H_4O

18. A 500.0 mL buffer solution contains 0.20 M acetic acid (CH_3COOH) and 0.30 M sodium acetate (CH_3COONa). Determine the pH of this solution be after the addition of 20.0 mL of 1.00 M NaOH. [$K_a = 1.8 \times 10^{-5}$]

    A. 4.41
    B. 4.74
    C. 5.07
    D. 4.56
    E. 4.92

19. A compound decomposes by a first-order process. If 25.0% of the compound decomposes in 60.0 minutes, the half-life of the compound is _____.

    A. 65 minutes
    B. 120 minutes
    C. 180 minutes
    D. 145 minutes
    E. 198 minutes

20. What is the binding energy (in J/mol or kJ/mol) of an electron in a metal whose threshold frequency for photoelectrons is $2.50 \times 10^{14}\ s^{-1}$? (Plank's constant, h = 6.626×10^{-34} J . s)

    A. 1.66×10^{-19} J/mol
    B. 2.75×10^{-43} J/mol
    C. 7.22×10^{17} kJ/mol
    D. 1.20×10^{-6} J/mol
    E. 99.7 kJ/mol

21. The density of lead is 11.4 g/cm^3. The mass of a lead ball with a radius of 0.50 mm is _____ g. ($V_{sphere} = \frac{4}{3}\pi r^3$).

    A. 6.0×10^{-3}
    B. 6.0×10^{0}
    C. 4.6×10^{-2}
    D. 4.6×10^{-5}
    E. 4.6×10^{0}

22. A certain mass of carbon reacts with 128 g of oxygen to form carbon monoxide. _____ grams of oxygen would react with that same mass of carbon to form carbon dioxide, according to the law of multiple proportions.

    A. 25.6
    B. 256
    C. 64.0
    D. 128
    E. 1280

23. When octane (C_8H_{18}) is burned in a particular internal combustion engine, the yield of products (carbon dioxide and water) is 93%. What mass of carbon dioxide will be produced in this engine when 15.0 g of octane is burned with 15.0 g of oxygen gas?

    A. 13 g
    B. 12 g
    C. 21 g
    D. 54 g
    E. 43 g

24. Calculate the percent ionization of cyanic acid (HCNO, $K_a = 2.0 \times 10^{-4}$) in a buffer solution that is 0.50 M HCNO and 0.10 M NaCNO.

    A. 0.02%
    B. 0.10%
    C. 0.20%
    D. 2.0%
    E. 20%

25. The following reaction is second order in [A] and the rate constant is 0.039 $M^{-1}.s^{-1}$:

    $$A \rightarrow B$$

    The concentration of A was 0.30 M at 23 s. The initial concentration of A was _____ M.

    A. 2.4
    B. 0.27
    C. 3.7
    D. 0.41
    E. 0.012

26. The de Broglie wavelength of an electron with a velocity of 6.00×10^6 m/s is _____ m. The mass of the electron is 9.11×10^{-28} g.

    A. 8.25×10^{9}
    B. 8.25×10^{9}
    C. 1.21×10^{-16}
    D. 1.21×10^{-13}
    E. 1.21×10^{-10}

27. Use the given standard reduction potentials in (1) and (2) to calculate the standard cell potential, $E°_{cell}$, for the reaction $Ni^{2+}(aq) + 2\ Fe^{2+}(aq) \rightarrow Ni(s) + 2\ Fe^{3+}(aq)$.

    (1) $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ $\quad E° = –0.23$ V

    (2) $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ $\quad E° = 0.77$ V

    A. +2.81 V.
    B. +1.00 V.
    C. +0.54 V.
    D. –2.81 V.
    E. –1.00 V.

28. The solubility of a salt in water usually increases with increasing temperature because the process is

    A. endothermic, so the higher temperature favors dissolution.
    B. exothermic, so the higher temperature favors dissolution.
    C. exothermic, so dissolution occurs faster.
    D. endothermic, so dissolution occurs faster.
    E. at equilibrium, so the higher temperature favors dissolution.

29. A certain large iron containing protein has a molar mass of 6.45×10^4 g/mol. The iron in this protein amounts to 0.346 % of the total mass. How many iron atoms are there in one molecule of this protein?

    A. 4
    B. 400
    C. 223
    D. 1
    E. 3338

30. The electron configuration of $^{23}_{11}\mathrm{Na}^+$ is

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

31. The number of unpaired electrons in the copper(I) ion is

A. 2 B. 3 C. 4 D. 5 E. 0

32. How much water must be added to dilute 3.5 M NaCℓ to 250 mL of 0.45 M NaCℓ?

A. 1.9×10^3 mL B. 1.6×10^2 mL C. 32 mL D. 0.032 mL E. 2.18×10^2 mL

33. This equilibrium is established

$$\underset{\text{pale yellow}}{Fe^{3+}(aq)} + \underset{\text{colorless}}{SCN^-(aq)} \rightleftharpoons \underset{\text{red}}{FeSCN^{2+}(aq)}$$

Which addition leads to the described color change?

A. Added Ag^+ reacts with SCN^- and the red color intensity increases.
B. $Fe(NO_3)_3$ is added and the red color intensity decreases.
C. Added Hg^{2+} reacts with SCN^- and the red color intensity decreases.
D. NaSCN is added and the red color intensity decreases.
E. The temperature is increased and the red color intensity increases.

34. The solubility of barium fluoride is 0.018 mol/L at 25 ^{0}C. What is the solubility product constant at 25 ^{0}C?

A. 3.6×10^{-2}
B. 2.3×10^{-5}
C. 1.2×10^{-5}
D. 5.8×10^{-6}
E. 1.0×10^{-3}

35. Based on the following data, which elements are most likely to form ionic bonds when joined with each other?

1st ionization energy of **R**	520 kJ/mol
1st ionization energy of **Z**	1310 kJ/mol
electron affinity of **Z**	72 kJ/mol
electron affinity of **Q**	364 kJ/mol
electron affinity of **T**	342 kJ/mol

A. **Q** and **T** B. **R** and **Q** C. **Q** and **Z** D. **T** and **Z** E. **R** and **Z**

36. Which comparison of sulfur with a neighboring element is true?

A. S has a higher electronegativity than Cℓ.
B. S has a lower electronegativity than P.
C. S has a lower ionization energy than O.
D. S has a lower ionization energy than Se.
E. S has a smaller radius than Cℓ.

37. What is the freezing point of a solution prepared by dissolving 12.8 g of naphthalene ($C_{10}H_8$) in 500 g of benzene (C_6H_6)? The normal freezing point of benzene 5.48 ^{0}C and its k_f is 5.12 ^{0}C/*m*.

A. 6.50 ^{0}C B. -4.46 ^{0}C C. –1.02 ^{0}C D. 4.46 ^{0}C E. 1.02 ^{0}C

38. Which statement predicts and explains the relationship between the boiling points of 0.25 *m* aqueous solutions of sucrose ($C_{12}H_{22}O_{11}$) and calcium chloride ($CaC\ell_2$)?

A. The boiling point of the sugar solution is higher because of hydrogen bonding between sugar molecules.
B. The boiling point of the calcium chloride solution is higher because it has more particles in solution.
C. The boiling point of the sugar solution is higher because it has more particles in solution.
D. The boiling point of the sugar solution is higher because of hydrogen bonding between sugar molecules and water molecules.
E. The boiling points of the two solutions are identical because they are at identical molalities.

39. Which of these types of electromagnetic radiation has the shortest wavelength?

A. ultraviolet
B. radio waves
C. visible
D. X-rays
E. Infrared

40. When an electron falls from n = 3 to n = 2 in a hydrogen atom, what is the value of the energy released?

A. 3.63×10^{-19} J
B. 2.18×10^{-18} J
C. 1.09×10^{-17} J
D. 4.36×10^{-18} J
E. 3.03×10^{-19} J