Academic Challenge

EASTERN ILLINOIS UNIVERSITY

2019 Academic Challenge

CHEMISTRY TEST – SECTIONAL

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

Chemistry Test (Sectional) – 2019

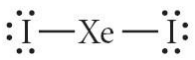
1. Chemical changes can turn substances into other substances. The ability of a substance to go through a chemical change is called ____

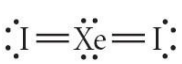
   A. Evaporation
   B. Reactivity
   C. Boiling
   D. Deposition
   E. Condensation

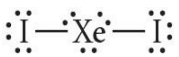
2. Which of the following is the correct formula of magnesium nitrite?

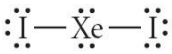
   A. $Mg(NO_2)_2$ B. $Mg(NO_3)_2$ C. MgN D. Mg_3N_2 E. $Mg(NO_2)_3$

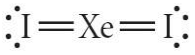
3. Which of the following represents the best Lewis structure for XeI_2.

   A. 

   B. 

   C. 

   D. 

   E. 

4. Determine the specific heat capacity of an alloy that requires 59.3 kJ to raise the temperature of 150.0 g alloy from 298 K to 398 K.

   A. 3.95 J/g.°C
   B. 4.38 J/g.°C
   C. 2.29 J/g.°C
   D. 2.53 J/g.°C
   E. 1.87 J/g.°C

5. Identify the number of electron groups around an inner atom in a molecule with sp^3d^2 hybridization.

   A. 2 B. 2 C. 3 D. 4 E. 6

6. Which of the following places would you expect to display the lowest boiling point of water?

   A. Death Valley, 282 feet below sea level
   B. a pressurized passenger jet, 35,000 feet
   C. New Orleans, sea level
   D. Mt. Everest, 29,035 feet
   E. Denver, Colorado, 5280 feet

7. What is the name for $Ba_3(PO_4)_2$?

   A. barium(III) phosphite
   B. barium(II) phosphite
   C. barium phosphate
   D. tri barium phosphorustetraoxide
   E. barium phosphite

8. Place the following in order of increasing entropy at 298 K.

   Ne Xe He Ar Kr

   A. He < Kr < Ne < Ar < Xe
   B. Xe < Kr < Ar < Ne < He
   C. Ar < He < Ar < Ne < Kr
   D. Ar < Ne < Xe < Kr < He
   E. He < Ne < Ar < Kr < Xe

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

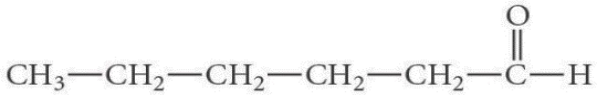
   1) NH_3 2) $CH_3CH_2CH_2NH_2$ 3) $CH_3CH_2NHCH_2CH_3$ 4) $(CH_3CH_2)_2NCH_2CH_3$

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

10. What is the concentration of hydroxide ions in pure water at 30.0 °C, if K_W at this temperature is 1.47×10^{-14}?

    A. 1.00×10^{-7} M
    B. 1.30×10^{-7} M
    C. 1.47×10^{-7} M
    D. 8.93×10^{-8} M
    E. 1.21×10^{-7} M

11. Name the following compound.



A. pentanal B. 1- pentanol C. hexanal D. 1- hexanone E. 1- hexanyl

12. Identify the species capable of displaying amphoteric behavior.

A. CO_3^{2-}
B. HF
C. NH_4^+
D. HPO_4^{2-}
E. None of the above are amphoteric.

13. A 0.465 g sample of an unknown compound occupies 245 mL at 298 K and 1.22 atm. What is the molar mass of the unknown compound?

A. 26.3 g/mol
B. 33.9 g/mol
C. 12.2 g/mol
D. 38.1 g/mol
E. 81.8 g/mol

14. The following reaction represents what nuclear process?

$$^{214}_{82}\text{Pb} \rightarrow {}^{0}_{-1}\text{e} + {}^{215}_{83}\text{Bi}$$

A. alpha emission
B. beta emission
C. gamma emission
D. electron capture
E. neutron bombardment

15. A wooden object has a mass of 10.782 g and occupies a volume of 13.72 mL. What is the density of the object determined to an appropriate number of significant figures?

A. 8×10^{-1} g/mL
B. 7.9×10^{-1} g/mL
C. 7.86×10^{-1} g/mL
D. 7.859×10^{-1} g/mL
E. 7.8586×10^{-1} g/mL

16. An oxide ion, O^{2-}, has:

    A. 8 protons and 10 electrons
    B. 10 protons and 8 electrons
    C. 8 protons and 9 electrons
    D. 8 protons and 7 electrons
    E. 10 protons and 7 electrons

17. Calculate the percentage by mass of nitrogen in $PtC\ell_2(NH_3)_2$.

    A. 4.67
    B. 9.34
    C. 9.90
    D. 4.95
    E. 12.67

18. Which pair of elements would be most likely to form an ionic compound?

    A. P and Br
    B. Zn and K
    C. F and Aℓ
    D. C and S
    E. Aℓ and Rb

19. Of the following, _____ is the largest mass.

    A. 2.5×10^{1} kg
    B. 2.5×10^{-2} mg
    C. 2.5×10^{15} pg
    D. 2.5×10^{9} fg
    E. 2.5×10^{10} ng

20. The mineral hausmannite is a compound of manganese-55 and oxygen-16. If 72% of the mass of hausmannite is due to manganese, what is the empirical formula of hausmannite?

    A. MnO
    B. Mn_3O
    C. Mn_3O_4
    D. Mn_4O_3
    E. MnO_3

21. Assuming equal concentrations of conjugate base and acid, which one of the following mixtures is suitable for making a buffer solution with an optimum pH of 9.2 – 9.3?

A. CH_3COONa / CH_3COOH ($K_a = 1.8 \times 10^{-5}$)
B. NH_3 / $NH_4C\ell$ ($K_a = 5.6 \times 10^{-10}$)
C. $NaOC\ell$ / $HOC\ell$ ($K_a = 3.2 \times 10^{-8}$)
D. $NaNO_2$ / HNO_2 ($K_a = 4.5 \times 10^{-4}$)
E. $NaC\ell$ / $HC\ell$

22. The best rate law expression for the following reaction and data is _____.

	A + B → Product		
Experiment #	[A], (M)	[B], (M)	Initial rate (M/s)
1	0.273	0.763	2.83
2	0.273	1.526	2.83
3	0.819	0.763	25.47

A. k[A][B]
B. k[B]
C. $k[A]^2[B]$
D. $k[A]^2[B]^2$
E. $k[A]^2$

23. What is the de Broglie wavelength of a 6.0 gram bullet traveling at the speed of sound. The speed of sound is 331 m/sec. Useful info, Planck's constant, $h = 6.626 \times 10^{-34}$ m^2 kg / s.

A. 2.7×10^{-34} m
B. 3.3×10^{-34} m
C. 3.35×10^{-33} m
D. 2.7×10^{-37} m
E. 6.6×10^{-31} m

24. "No two electrons in an atom can have the same four quantum numbers" is a statement of

A. the Pauli exclusion principle.
B. Bohr's equation.
C. Hund's rule.
D. de Broglie's relation.
E. Dalton's atomic theory.

25. A certain electrochemical cell has for its cell reaction:

$$Zn + HgO \rightarrow ZnO + Hg$$

Which is the half-reaction occurring at the *anode*?

A. $HgO + 2e^- \rightarrow Hg + O^{2-}$
B. $Zn^{2+} + 2e^- \rightarrow Zn$
C. $ZnO + 2e^- \rightarrow Zn$
D. $Zn \rightarrow Zn^{2+} + 2e^-$
E. None of the above

26. The following reaction occurs in aqueous solution:

$$NH_4^+(aq) + NO_2^-(aq) \rightarrow N_2(g) + 2\ H_2O(\ell)$$

The data below is obtained at 25 °C.

$[NH_4^+]$, (M)	$[NO_2^-]$ (M)	Initial rate (M/s)
0.0100	0.200	3.2×10^{-3}
0.0200	0.200	6.4×10^{-3}

The order of the reaction in NH_4^+ is _____.

A. –2
B. –1
C. +1
D. +2
E. 0

27. What is the balanced overall (net) cell reaction for the following notation for an electrochemical cell?

$$Pt(s) \mid H_2(g) \mid H^+(aq) \parallel Ag^+(aq) \mid Ag(s)$$

A. $2\ H^+(aq) + 2\ Ag^+(aq) \rightarrow H_2(g) + 2\ Ag(s)$
B. $H_2(g) + 2\ Ag(s) \rightarrow H^+(aq) + 2\ Ag^+(aq)$
C. $2\ H^+(aq) + 2\ Ag(s) \rightarrow H_2(g) + 2\ Ag^+(aq)$
D. $H_2(g) + Ag^+(aq) \rightarrow H^+(aq) + Ag(s)$
E. $H_2(g) + 2\ Ag^+(aq) \rightarrow 2\ H^+(aq) + 2\ Ag(s)$

28. What volume of 0.100 M $SO_3^{2-}(aq)$ is needed to titrate 24.0 mL of 0.200 M $Fe^{3+}(aq)$? This equation represents the reaction that takes place during the titration.

$$2\ Fe^{3+}(aq) + SO_3^{2-}(aq) + H_2O(\ell) \rightarrow 2\ Fe^{2+}(aq) + SO_4^{2-}(aq) + 2\ H^+(aq)$$

A. 48.0 mL
B. 24.0 mL
C. 12.0 mL
D. 6.00 mL
E. 20.0 mL

29. Which electron configuration is ***impossible***?

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

30. When a sample of NO_2 is placed in a container, this equilibrium is rapidly established.

$$2\ NO_2(g) \rightleftharpoons N_2O_4(g)$$

If this equilibrium mixture is a darker color at high temperatures and also darker color at low pressures (expanded volumes), which statement about the reaction is true?

A. The reaction is exothermic and NO_2 is darker in color than N_2O_4.
B. The reaction is exothermic and N_2O_4 is darker in color than NO_2.
C. The reaction is endothermic and NO_2 is darker in color than N_2O_4.
D. The reaction is endothermic and N_2O_4 is darker in color than NO_2.
E. Not enough information provided.

31. Typical "hard" water contains about 2.0×10^{-3} mol of Ca^{2+} per liter. Calculate the maximum concentration of fluoride ion that could be present in hard water. The value of K_{sp} for calcium fluoride is 4.0×10^{-11}.

A. 2.0×10^{-3} M
B. 1.0×10^{-8} M
C. 1.0×10^{-5} M
D. 2.0×10^{-8} M
E. 1.4×10^{-4} M

32. The number of unpaired electrons in a gaseous selenium atom is _____.

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

33. What is the maximum mass of ammonium sulfate (132 g/mol) that could be formed from 17 kg of NH_3 (17 g/mol) and 200 kg of solution containing 49% H_2SO_4 (98 g/mol) by mass? This equation represents the reaction.

$$2\ NH_3(g)\ +\ H_2SO_4(aq)\ \rightarrow\ (NH_4)_2SO_4(s)$$

A. 217 kg
B. 132 kg
C. 115 kg
D. 66 kg
E. 269 kg

34. If the formula of an oxide of element **X** is $\mathbf{X}_2O_3$, what is the formula of the chloride of **X**?

A. $\mathbf{X}_3C\ell$ B. $\mathbf{X}C\ell$ C. $\mathbf{X}C\ell_3$ D. $\mathbf{X}C\ell_6$ E. $\mathbf{X}_3C\ell_2$

35. What is the energy of a photon with a wavelength of 93.8 nm?

A. 2.12×10^{-18} J
B. 2.12×10^{15} J
C. 1.07×10^{7} J
D. 3.13×10^{-16} J
E. 2.12×10^{-27} J

36. A solution is made by dissolving 60 g of NaOH (40 g/mol) in enough distilled water to make 300 mL of a stock solution. What volumes of this solution and distilled water, when mixed, will result in a solution that is approximately 1 M NaOH?

A. 20 mL stock solution and 100 mL distilled water
B. 20 mL stock solution and 80 mL distilled water
C. 60 mL stock solution and 30 mL distilled water
D. 60 mL stock solution and 90 mL distilled water
E. 20 mL stock solution and 120 mL distilled water

37. What is the mole fraction of water in 200 g of 95 % by mass ethanol, C_2H_5OH?

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

38. The first three ionization energies of an element **X** are 590, 1145, 4912 kJ/mol. What is the likely formula for a stable ion of **X**?

A. $\mathbf{X}^{+}$ B. $\mathbf{X}^{-}$ C. $\mathbf{X}^{3+}$ D. $\mathbf{X}^{2+}$ E. $\mathbf{X}^{2-}$

39. 800 g of ethanol, C_2H_5OH, was added to 8.0×10^3 g of water ($k_f = 1.86\ ^{o}C/m$). How much would this lower the freezing point?

A. 3.2 ^{o}C B. 8.2 ^{o}C C. 16 ^{o}C D. 4.0 ^{o}C E. 1.2 ^{o}C

40. Which electron transition in a hydrogen atom is associated with the smallest emission of energy?

A. n = 2 to n = 1
B. n = 2 to n = 3
C. n = 2 to n = 4
D. n = 3 to n = 1
E. n = 3 to n = 2