2020 Academic Challenge

CHEMISTRY TEST – REGIONAL

Chemistry Test Production Team

Iffat Ali, Lake Land College – Author/Team Leader
Gregory Capitosti, Lake Land College – Author/Reviewer
David Wilson, Parkland College – Author

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
2020 Regional Chemistry Exam

1. Which of the following is solid at room temperature and at 1 atm pressure?

   A. iodine B. mercury C. water D. bromine E. hydrogen

2. Consider CO_2 and SO_2. Choose the correct answer.

   A. Both molecules are polar.
   B. Both molecules are nonpolar.
   C. CO_2 is polar whereas SO_2 is nonpolar.
   D. SO_2 is polar whereas CO_2 is nonpolar.
   E. None of the above is correct.

3. At what temperature does a perfect crystalline solid have S = 0?

   A. 0 K
   B. 0 °C
   C. 100 °C
   D. 273 K
   E. It is not possible for a substance to have S = 0.

4. Choose the compound that exhibits hydrogen bonding as its strongest intermolecular force.

   A. SBr_2
   B. C_2H_6
   C. CH_3OH
   D. CH_2Br_2
   E. None of the above compounds exhibit hydrogen bonding.

5. Identify the diprotic acid.

   A. HNO_3 B. HBr C. CH_3COOH D. H_2SO_4 E. $HC\ell O_4$

6. When **m** and **n** represent gram mass and number of moles respectively for a gaseous substance, which of the following relationship will solve for its molar mass **M**?

   A. $\frac{mRT}{PV}$ B. $\frac{PVm}{RT}$ C. $\frac{nRT}{PV}$ D. $\frac{mRT}{nPV}$ E. $\frac{nPT}{RV}$

7. Describe the changes occur during gamma ray emission.

   A. The mass number and atomic number decreases.
   B. The mass number and atomic number increases.
   C. The mass number is unchanged and the atomic number decreases.
   D. The mass number decreases and the atomic number is unchanged.
   E. The mass number and atomic number do not change.

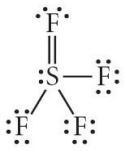
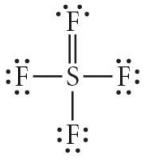
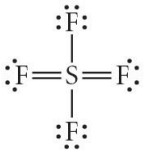
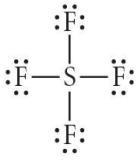
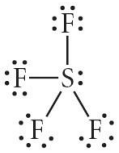
8. Which of the following is expected to dissolve in water?

A. $AgC\ell$ B. PbS C. Na_2SO_4 D. $BaSO_4$ E. $Hg_2C\ell_2$

9. The correct name for SnO is

A. tin(I) oxide B. tin(II) oxide C. tin(III) oxide D. tin(IV) oxide E. tin oxide

10. Which of the following represents the best Lewis structure for SF_4?

A.  B.  C.  D.  E. 

11. Calculate the $\Delta G°_{rxn}$ using the following information.

	$2\ HNO_3(aq)$	+ $NO(g)$	→	$3\ NO_2(g)$	+ $H_2O(\ell)$
$\Delta G°_f$ (kJ/mol)	–110.9			87.6	51.3	–237.1

A. –162.5 kJ
B. +51.0 kJ
C. –54.5 kJ
D. +171.1 kJ
E. –87.6 kJ

12. Identify the gas particle that travels the slowest at a given temperature.

A. H_2 B. He C. Ne D. Ar E. Kr

13. Which of the following is the correct formula of sodium perchlorate?

A. $NaC\ell O$ B. $NaC\ell O_2$ C. $NaC\ell O_3$ D. $NaC\ell O_4$ E. $Na_2C\ell O_2$

14. What is the hydroxide ion concentration of a NaOH solution that has a pH of 9.20?

A. 6.31×10^{-10} M
B. 1.58×10^{-5} M
C. 4.80 M
D. 9.20 M
E. None of the above

15. What is Δn for the following equation in relating K_c to K_p?

$$2\ Rb(s) + 2\ H_2O(\ell) \leftrightarrow 2\ RbOH(aq) + H_2(g)$$

A. 2 B. –1 C. 2 D. 3 E. 1

16. Choose the valence orbital diagram that represents the ground state of Sr^{2+}.

A. $\underline{\uparrow\downarrow}_{5s}\ \ \underline{\uparrow}_{5p}\ \underline{\uparrow}_{5p}\ \underline{\ \ }_{5p}$

B. $\underline{\uparrow\downarrow}_{5s}$

C. $\underline{\uparrow\downarrow}_{4s}\ \ \underline{\uparrow\downarrow}_{4p}\ \underline{\uparrow\downarrow}_{4p}\ \underline{\uparrow\downarrow}_{4p}$

D. $\underline{\uparrow\downarrow}_{4p}\ \underline{\uparrow\downarrow}_{4p}\ \underline{\uparrow\downarrow}_{4p}$

E. $\underline{\uparrow\downarrow}_{5s}\ \ \underline{\uparrow}_{4d}\ \underline{\uparrow}_{4d}\ \underline{\ \ }_{4d}\ \ \underline{\ \ }_{4d}\ \underline{\ \ }_{4d}$

17. All of the following compounds are soluble except

A. $ZnC\ell_2$.
B. $Pb(NO_3)_2$.
C. $Cu(C_2H_3O_2)_2$.
D. $Ba(OH)_2$.
E. AgBr.

18. Give the percent yield when 28.16 g of CO_2 are formed from the reaction of C_8H_{18} with 8.00 moles of O_2.

$$2\ C_8H_{18}\ +\ 25\ O_2\ \rightarrow\ 16\ CO_2\ +\ 18\ H_2O$$

A. 20.00 %
B. 25.00 %
C. 50.00 %
D. 12.50 %
E. 6.25%

19. The boiling point elevation of an aqueous sucrose solution is found to be 0.39 ^{0} C. What mass of sucrose (molar mass = 342.30 g/mol) would be needed to dissolve in 500.0 g of water?
k_b = 0.512 ^{0} C/*m*

A. 130 g
B. 261 g
C. 528 g
D. 762 g
E. 223 g

20. Which species has the highest ionization energy?

A. $A\ell^{2+}$ B. Mg C. $A\ell^{+}$ D. Mg^{+} E. Mg^{2+}

21. How many molecules of H_2S are required to form 79.0 g of sulfur according to the following reaction? Assume excess SO_2.

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

A. 3.17×10^{25}
B. 9.89×10^{23}
C. 2.44×10^{23}
D. 5.06×10^{25}
E. 1.48×10^{24}

22. An FM radio station broadcasts electromagnetic radiation at a frequency of 92.6 MHz. The wavelength of this radiation is _____ m.

A. 3.24
B. 2.78×10^{10}
C. 3.24×10^{6}
D. 2.78×10^{16}
E. 0.309

23. A solution is prepared by dissolving 49.3 g of KBr in enough water to form 473 mL of solution. Calculate the mass % of KBr in the solution if the density is 1.12 g/mL.

A. 10.1 %
B. 9.31 %
C. 8.57 %
D. 11.7 %
E. 10.4%

24. Which halogen is considered the most reactive?

A. Br_2 B. I_2 C. F_2 D. $C\ell_2$ E. At_2

25. The element that corresponds to the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$.

A. iron B. titanium C. chromium D. manganese E. vanadium

26. Calculate the energy of the violet light emitted by a hydrogen atom with a wavelength of 410.1 nm.

A. 5.27×10^{-19} J
B. 2.06×10^{-19} J
C. 8.13×10^{-19} J
D. 4.85×10^{-19} J
E. 1.23×10^{-19} J

27. Consider the following balanced equation. What mass, in g, of CO_2 can be formed from 288 mg of O_2? Assume that there is excess C_3H_7SH present.

$$C_3H_7SH(\ell) + 6\ O_2(g) \rightarrow 3\ CO_2(g) + SO_2(g) + 4\ H_2(g)$$

A. 0.126 g CO_2
B. 0.198 g CO_2
C. 0.396 g CO_2
D. 0.792 g CO_2
E. 0.209 g CO_2

28. When calculating mass by multiplying 0.09020 mole by 15.109 g/mole, how many digits should be included in your answer?

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

29. Which of the following lengths is the greatest?

A. 150,000 cm
B. 150 m
C. 0.15 km
D. 150,000,000,000 nm
E. 1,500 mm

30. How many moles of hydrogen atoms would be found in 20.0 moles of ammonia (NH_3)?

A. 3.00 mol
B. 5.00 mol
C. 20.0 mol
D. 60.0 mol
E. 80.0 mol

31. Which of the following can be described as a polyatomic ion?

A. NH_3 B. S_4 C. Se^{2-} D. $C_4H_8O_4$ E. O_2^{2-}

32. In a salt lattice structure, there are cations with a 2+ charge and anions with a 1– charge. Which of the following conclusions is valid about this structure?

A. The number of cations equals the number of anions.
B. There are 4 times as many cations as anions.
C. There are 4 times as many anions as cations.
D. There are twice as many cations as anions.
E. There are twice as many anions as cations.

33. How many neutrons would you find in an atom with a mass number of 25 and an atomic number of 11?

A. 11 B. 14 C. 25 D. 36 E. 55

34. What is the mass percent of carbon in CO_2?

A. 12%
B. 27%
C. 33%
D. 36%
E. 75%

35. A hydrocarbon with a molar mass of 192 g/mol is known to contain 12 atoms of carbon per molecule. What is the empirical formula for this hydrocarbon?

A. CH
B. CH_2
C. C_2H
D. CH_4
E. C_4H

36. Which of the following combinations of reagents would be most suitable for preparing a buffer solution?

A. $HC_2H_3O_2$, $NaC_2H_3O_2$
B. $HC\ell$, $NaC_2H_3O_2$
C. $HC\ell$, $HC_2H_3O_2$
D. $NaC\ell$, $NaC_2H_3O_2$
E. $HC_2H_3O_2$, NaOH

37. What is the overall order for the reaction A + 2 B + C $\rightarrow$ D if its rate law is rate = $k[A][B]^2$?

A. 1st order
B. 2nd order
C. 3rd order
D. 4th order
E. It cannot be determined without knowing rate measurements or the reaction's mechanism.

38. Which of the following observations is supported by the equation, $E = h\nu$?

A. Energy of any infinitesimal size can be released by a decaying electron moving from one shell of an atom to another.
B. Energy and frequency are inversely proportional.
C. The energy of light is contained in small packets called quanta.
D. The wavelength of light is proportional to its frequency.
E. Light photons are waves, not particles.

39. In order for a galvanic electrochemical cell to be spontaneous it must meet which of these criteria?

A. An E_{cell} value that is greater than 0
B. An E_{cell} value that is equal to 0
C. An E_{cell} value that is less than 0
D. It depends on what the electrode materials are composed of.
E. It depends on the concentration of ions in the solutions at both half cells.

40. What is the oxidation state of the reducing agent in this reaction?

$$2\ Ag(s) + H_2S(g) \rightarrow Ag_2S(g) + H_2(g)$$

A. –2
B. –1
C. 0
D. +1
E. +2