2018 Academic Challenge

CHEMISTRY TEST – REGIONAL

– This Test Consists of 40 Questions –

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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** ***

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

Periodic Table of the Elements

1A																	8A
1 H 1.008	2A											3A	4A	5A	6A	7A	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

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

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

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

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

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

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

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

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

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

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

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

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

pH = -log [H$_3$O$^+$]

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 × 10^{-14}

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

B = -2.18x10^{-18} J

1.0 kg = 2.2 lb

N$_A$ = 6.022x10^{23}

1.0 in = 2.54 cm

1 atm = 101,325 Pa = 1.01325 bar

1 lb = 453.59 g

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

c = 2.998 × 10^8 m/s

h = 6.626 x 10^{-34} J$\cdot$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.

1. Which of the following equations represents an acid-base neutralization reaction?

   A. $HNO_3 + KOH \rightarrow KNO_3 + H_2O$
   B. $H_2SO_4 + Zn \rightarrow ZnSO_4 + H_2$
   C. $Ba(OH)_2 + Na_2SO_4 \rightarrow BaSO_4 + 2\ NaOH$
   D. all are correct
   E. no correct response

2. Assign the following reaction to one of the reaction classifications provided.

   $$K_2CO_3 \rightarrow K_2O + CO_2$$

   A. decomposition
   B. displacement
   C. combination
   D. exchange
   E. redox

3. According to Charles's Law, at what temperature (Kelvin) would a gas have no volume in theory?

   A. 100 °C   B. 0 °C   C. 0 K   D. 273 K   E. –273 K

4. Which of the following describes an endothermic reaction?

   A. a reaction that causes the temperature of the surroundings to rise
   B. a reaction in which the change in enthalpy is less than zero
   C. a reaction that transfers heat from the system into the surroundings
   D. a reaction that never yields any product
   E. a reaction that transfers heat from the surroundings into the system

5. Which of the following types of radiation is composed of particles with a charge and mass identical to that of an electron?

   A. α radiation
   B. β radiation
   C. γ radiation
   D. ω radiation
   E. x radiation

6. A molecule of caffeine consists of 8 carbon atoms, 10 hydrogen atoms, 4 nitrogen atoms, and 2 oxygen atoms. Which of the following represents the empirical formula for caffeine?

   A. $C_4H_5N_2O_2$
   B. $C_{16}H_{20}N_8O_4$
   C. $C_8H_{10}Ni_4O_2$
   D. $C_4H_5N_2O$
   E. $C_8H_{10}N_4O_2$

7. A radio station broadcasts at a frequency of 107.1 megahertz. What is the wavelength of the radio waves broadcast by the station?

   A. 3.21×10^{18} m
   B. 2.80×10^{12} m
   C. 2.80×10^{-2} m
   D. 0.357 m
   E. 2.80 m

8. The correct assignment of oxidation numbers to the elements in the polyatomic ion SO_3^{2-} would be

   A. +4 for S and –2 for O
   B. +4 for S and –6 for O
   C. +6 for S and –2 for O
   D. +6 for S and –6 for O
   E. +3 for S and –2 for O

9. Which of the molecules shown below is most likely to be polar species?

   A. H_2 B. CO_2 C. N_2 D. CH_4 E. SO_2

10. Arrange the following phases of matter in **increasing order** of amount of molecular freedom

    A. liquid, gas, solid
    B. gas, solid, liquid
    C. gas, liquid, solid
    D. solid, liquid, gas
    E. no correct answer

11. All antacids are _____

    A. strong bases
    B. weak bases
    C. strong acids
    D. weak acids
    E. pH neutral

12. How many grams of iodine are produced from 7 moles of chlorine according to the following reaction?

    $$3\ C\ell_2 + 2\ FeI_2 \rightarrow 2\ FeC\ell_3 + 2\ I_2$$

    A. 183.9 g
    B. 592.6 g
    C. 2665 g
    D. 1185 g
    E. 700.0 g

13. A 10 liter tank contains 1 mol of hydrogen gas at a pressure of 2 atmosphere. What is the temperature (in Celsius) of the gas in the tank?

    A. 234.5 °C
    B. –29.4 °C
    C. –151.2 °C
    D. 1250 °C
    E. 250 °C

14. What is the percentage of iron in iron(III) oxide?

    A. 30%   B. 33%   C. 40%   D. 60%   E. 70%

15. What is the maximum number of electrons in a 3d set of orbitals?

    A. 2   B. 6   C. 14   D. 10   E. 8

16. From the periodic table, the number of valence electrons for most of the main group elements may be determined directly from the

    A. period number
    B. atomic number
    C. group number
    D. atomic number
    E. mass number

17. What is the reason for the boiling point of water (H_2O) being so much higher than the boiling point of dihydrogen sulfide (H_2S)?

    A. water is able to hydrogen bond, hydrogen sulfide is not able to hydrogen bond
    B. water is drinkable and dihydrogen sulfide is not
    C. oxygen in water has the electrons in the second energy level. Sulfur has electrons in the third energy level
    D. it is a mistake; water has a lower boiling point
    E. water is explosive and dihydrogen sulfide is not

18. What is the coefficient for oxygen in the properly balanced chemical equation for the combustion of propane and oxygen gas to form carbon dioxide gas and water?

    $$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

    A. 1   B. 5   C. 2   D. 10   E. 3

19. Predict what will happen to the volume of a gas if there is an increase in pressure when the temperature and amount of the gas are held constant.

    A. the volume will increase
    B. the volume will remain the same
    C. the volume will decrease
    D. all are correct
    E. no correct answer

20. How many grams of potassium nitrate are produced when 424 g of potassium phosphate are used in the following reaction?

$$K_3PO_4 + Al(NO_3)_3 \rightarrow 3\ KNO_3 + AlPO_4$$
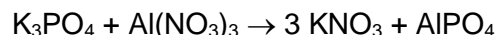
   A. 204 g
   B. 302 g
   C. 605 g
   D. 56 g
   E. 420 g

21. Which of the following could not be the molecular formula for an alkane molecule?

   A. $C_{10}H_{22}$ B. C_5H_{14} C. CH_4 D. $C_{24}H_{50}$ E. C_7H_{16}

22. Elements in groups IIA and VIIA of the periodic table would, respectively, form ions with charges of

   A. +2 and +7
   B. -2 and -7
   C. +2 and +1
   D. +2 and -1
   E. +2 and -7

23. A student performs an experiment to determine the density of a solution. The following results are obtained: 1.81 g/mL, 1.83 g/mL, 1.77 g/mL, 1.79 g/mL. If the actual value for the density of the solution is 1.38 g/mL, which statement below best describes the results?

   A. The results are accurate, but not precise.
   B. The results are both precise and accurate
   C. The results are precise, but not accurate.
   D. The results are neither precise nor accurate.
   E. Impossible to determine.

24. What is an example of a chemical property?

   A. buoyancy
   B. viscosity
   C. flammablilty
   D. color
   E. density

25. What is the formula of the compound formed between strontium ions and nitride ions?

   A. SrN   B. Sr_3N_2 C. Sr_2N_3 D. SrN_2 E. SrN_3

26. From left to right, each period of the periodic table ends in a(n) _____.

    A. noble gas
    B. active metal
    C. weakly active nonmetal
    D. highly active nonmetal
    E. halogen

27. A solute is typically identified as

    A. the material present in the largest amount in a solution.
    B. the material that dissolves in the solvent portion of a solution.
    C. being only dissolved in water.
    D. a homogeneous mixture of ions of molecules of two or more substances.
    E. the material that does the dissolving.

28. Which of the following solutions has the lowest vapor pressure?

    A. 0.5 M NaCl(aq)
    B. 0.1 M NaCl(aq)
    C. pure water
    D. 0.05 M NaCl(aq)
    E. all have the same vapor pressure

29. The conventional equilibrium constant expression (K_c) for the system as described by the following equation is:

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

    A. $\dfrac{[SO_2]^2}{[SO_3]}$

    B. $\dfrac{[SO_2]}{[O_2]}$

    C. $\dfrac{[SO_3]^2}{[SO_2]^2[O_2]}$

    D. $\dfrac{[SO_2]^2[O_2]}{[SO_3]^2}$

    E. $\dfrac{[SO_3]^2}{[SO_2]^2}$

30. Catalysts lower the activation energy of a reaction by:

    A. providing an alternate pathway for the reaction
    B. changing the value of ΔH for the reaction
    C. increasing the energy content of the reactants
    D. adding heat to the reaction system
    E. none of these

31. The total number of atoms present in one formula unit of $Co_2(SO_4)_3$ is

    A. 9   B. 11   C. 16   D. 10   E. 17

32. Which of the following is the **smallest** volume?

    A. 0.48 dL
    B. 2.1×10^3 mL
    C. 110 cL
    D. 3.6×10^2 kL
    E. 18 cm^3

33. The description "two substances present, one phase present" is correct for

    A. a mixture of ice and water
    B. a mixture of oil and water
    C. a mixture of sugar and water
    D. more than one correct response
    E. no correct response

34. The correct name for K_2S is _____.

    A. potassium sulfide
    B. potassium disulfide
    C. potassium bisulfide
    D. potassium sulfate
    E. dipotassium sulfate

35. Which element is expected to have properties most similar to those of sodium?

    A. Aluminum
    B. Sulfur
    C. Calcium
    D. Potassium
    E. Iron

36. A very large value of K_c, equilibrium constant, tells us which of the following?

    A. The reaction lies slightly to the left
    B. The reaction lies slightly to the right
    C. The reaction lies in the middle
    D. The reaction lies far to the left
    E. The reaction lies far to the right

37. The reaction A + 2 B → products has the following rate law: rate = k[A][B]^3. If the concentration of B is doubled while that of A is unchanged, by what factor will the rate of reaction increase?

    A. 2   B. 4   C. 6   D. 9   E. 8

38. What determines the chemical properties of an atom?

    A. the number of electrons in the first shell
    B. the number of electrons in the outer shell
    C. the number of protons in the first shell
    D. the number of protons in the outer shell
    E. the total number of electrons in all shells

39. What is the molarity of a solution that contains 1.50 mol HCℓ in 2.50 L of solution?

    A. 1.67 *M*   B. 1.40 *M*   C. 1.20 *M*   D. 0.600 *M*   E. 3.75 *M*

40. Which of the following statements correctly describes the subatomic particle called a neutron?

    A. Its mass is less than that of an electron.
    B. It has a negative charge.
    C. Its mass is similar to that of a proton.
    D. It contributes 15% of the mass of an atom.
    E. It has a positive charge.