2022 Academic Challenge

REGIONAL 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

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.

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1. Which property of a sample of water remains the same when it changes from a solid (ice) to a gas?

   A. density
   B. mass
   C. enthalpy
   D. volume
   E. all remain the same

2. Which of the following names correctly identifies the substance whose formula is $NaC\ell O_3$?

   A. sodium monochlorotrioxide
   B. sodium chlorine trioxide
   C. sodium hypochlorate
   D. sodium hyperchlorate
   E. sodium chlorate

3. Which property is not a physical property of matter?

   A. density
   B. freezing point
   C. combustibility
   D. boiling point
   E. conductivity

4. The total number of nonbonding electron pairs in the entire molecule of $PC\ell_3$ is:

   A. 10
   B. 6
   C. 9
   D. 8
   E. 1

5. What is the formula for sulfur trioxide?

   A. SO_3
   B. SO_3^{2-}
   C. SO_4
   D. S_3O
   E. none of these

6. When a 6.30 g gold plate is heated its temperature changed from 25.0 ^{o}C to 29.7 ^{o}C, how much energy has the object absorbed? The specific heat of gold at 25 ^{o}C is 0.129 J/g.^{o}C.

   A. 0.096 J
   B. 0.17 J
   C. 3.82 J
   D. 120 J
   E. 5.6 J

7. In which of the following molecules or ions is the octet rule violated?

   A. CO_2
   B. NO
   C. NH_4^+
   D. F_2
   E. CN^-

8. Place the molecules on right in the decreasing order of intermolecular forces. HF H_2 CO_2

   A. $CO_2 > H_2 > HF$
   B. $H_2 > CO_2 > HF$
   C. $HF > CO_2 > H_2$
   D. $CO_2 > HF > H_2$
   E. None of the choices

9. Choose all of the phase changes which are endothermic.

   I) melting II) freezing III) boiling IV) sublimation V) evaporation

   A. I, IV
   B. I, II
   C. I, III, V
   D. I, III, IV, V
   E. I, III

10. Which of the following is true when $[H_3O^+] = [OH^-]$?

   A. pH > 7
   B. pH < 7
   C. the solution is acidic
   D. the solution is neutral
   E. the solution is basic

11. What is the pH of a solution with a hydrogen ion concentration of 6.45×10^{-5} M?

A. 4.19
B. 7.57
C. 5.55
D. 9.03
E. 4.81

12. At constant temperature, the volume of a given amount of a gas is inversely proportional to its pressure. Which of the following expresses this relationship?

A. P/V = constant
B. PV = constant
C. P = V
D. PT = constant
E. PVT = constant

13. What is the volume of 12.0 g of C_3H_8 gas at 65.0 ^oC at a pressure of 2.00 atm?

A. 4.06 L
B. 178 L
C. 0.726 L
D. 32.0 L
E. 3.79 L

14. A piece of white paper would have sufficient density to stop the penetration of which of the following?

A. a photon
B. beta particle
C. gamma radiation
D. a high velocity electron
E. alpha particle

15. How many moles of chlorine are needed to produce 185.0 g of iron(III) chloride?

$$3\ C\ell_2\ +\ 2\ FeI_3\ \rightarrow\ 2\ FeC\ell_3\ +\ 3\ I_2$$

A. 1.711
B. 1.141
C. 0.7607
D. 3.422
E. 121.3

16. Which of the following solutions has the highest vapor pressure?

A. 1.0 *M* NaCℓ
B. 1.0 *M* $C_6H_{12}O_6$
C. 1.0 *M* $CaBr_2$
D. 1.0 *M* $Aℓ(NO_3)_2$
E. All have the same vapor pressure.

17. What is the correct equilibrium constant expression (K_c) for the reaction below?

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

A. $\frac{[SO_2]^2}{[SO_3]}$
B. $\frac{[SO_2]}{[O_2]}$
C. $\frac{[SO_3]^2}{[SO_2]^2[O_2]}$
D. $\frac{[SO_2]^2[O_2]}{[SO_3]^2}$
E. $\frac{[SO_3]^2}{[SO_2]^2}$

18. A radio station broadcasts at a frequency of 89.9 MHz. What is the energy of the radio signal?

A. 5.96×10^{-32} J
B. 5.96×10^{-29} J
C. 3.34×10^{6} J
D. 3.34 J
E. 5.96×10^{-26} J

19. Which of the following comparisons would be true?

A. Ga has a larger ionization energy than Aℓ.
B. Aℓ has a smaller radius than Si.
C. Si has a lower electron affinity than Aℓ.
D. Aℓ has a lower ionization energy than Si.
E. Si has a larger radius than Ga.

20. What is the mole fraction of HBr in a solution that contains 250 g of HBr in 100 mL of water?

A. 0.0309
B. 0.557
C. 0.443
D. 0.642
E. 0.358

21. What is the coefficient on oxygen when the chemical equation below is properly balanced?

$$C_4H_{10}O + O_2 \rightarrow CO_2 + H_2O$$

A. 6
B. 13
C. 26
D. 1
E. 4

22. Which of the following would represent a diamagnetic element?

A. $[Ar]4s^2 3d^6$
B. $[Ar]4s^2 3d^{10} 4p^3$
C. $[Ar]3d^8$
D. $[Ar]4s^1 3d^{10}$
E. $[Ar]4s^2 3d^{10}$

23. Which group of elements would have the highest electron affinities?

A. alkali metals
B. noble gases
C. halogens
D. alkaline earth metals
E. group 4A

24. Which electronic transition would produce light with the longest wavelength?

A. $4 \rightarrow 1$
B. $2 \rightarrow 1$
C. $3 \rightarrow 2$
D. $4 \rightarrow 3$
E. $3 \rightarrow 1$

25. Which correctly describes the solubility of solids with respect to increasing temperature?

A. always increases
B. increases if the dissolving process is endothermic
C. always decreases
D. increases if the dissolving process is exothermic
E. solid solubility is not affected by temperature

26. How many grams of hydrogen in 15.50 g of acetic acid, $HC_2H_3O_2$?

A. 1.043 g
B. 0.7820 g
C. 0.2555 g
D. 1.060 g
E. 0.7953 g

27. Which would be the correct set of quantum numbers for the last electron added in the orbital diagram of scandium?

A. n = 4 l = 2 m_l = -2 m_s = +½
B. n = 3 l = 0 m_l = 0 m_s = +½
C. n = 4 l = 0 m_l = 0 m_s = +½
D. n = 3 l = 2 m_l = –2 m_s = +½
E. n = 3 l = 1 m_l = –1 m_s = +½

28. How many degrees Celsius is equal to 412 K?

A. –211
B. –139
C. 59
D. 139
E. 211

29. A lab procedure asks you to use a pipette to dispense 5.00 mL of water and then weigh it in a tared beaker on an analytical balance. You then use a reference manual to find the density of water at room temperature and use that to convert 5.00 mL to a mass. You calculate a percent error between your measured mass and the reference mass. What is the point of this exercise?

A. to identify the maximum volume of the pipette
B. to determine the precision of the pipette
C. to identify any flaws in your pipetting technique
D. to verify the reference value for density
E. to determine the accuracy of the pipette

30. A standard graduated cylinder has markings for every 0.1 mL. Which of the following is a proper volume to report using this instrument?

A. 10 mL
B. 10. mL
C. 10.0 mL
D. 10.00 mL
E. 10.000 mL

31. An isoelectronic series of monatomic ions or atoms would have which of these in common?

A. the same atomic mass
B. the same number of neutrons
C. the same number of electrons
D. the same atomic number
E. the same electrical charge

32. How many electrons would you find in a neutral isotope of hydrogen-2?

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

33. How many atoms are there in a single molecule of diphosphorus pentoxide?

A. 2
B. 4
C. 5
D. 7
E. 10

34. A novel drug containing only carbon, hydrogen, and oxygen was decomposed through heating and found to contain 92.0 % by mass of carbon and oxygen combined. What would be the mass of hydrogen in a 25.0 gram sample of this drug?

A. 1.00 g
B. 2.00 g
C. 4.00 g
D. 6.00 g
E. 8.00 g

35. What is the empirical formula for a compound containing only two elements with 69.9 % of its mass due to iron and 30.1 % of its mass due to oxygen?

A. FeO
B. Fe_2O
C. FeO_2
D. Fe_3O_2
E. Fe_2O_3

36. Which of the following is the correct solubility product constant expression for silver chromate?

A. $K_{sp} = [Ag^+] \times [{CrO_4}^{2-}]$
B. $K_{sp} = [Ag^+]^2 \times [{CrO_4}^{2-}]$
C. $K_{sp} = 2 \times [Ag^+] \times [{CrO_4}^{2-}]$
D. $K_{sp} = 4 \times [Ag^+] \times [{CrO_4}^{2-}]$
E. $K_{sp} = [Ag^+] \times [{CrO_4}^{2-}]^2$

37. Geologists find Pb-210 to be the most interesting of the lead isotopes because of its relatively long half-life of 22.3 years. What is the rate constant (k) for the first order decay of this isotope?

A. 0.0311 yr^{-1}
B. 32.2 yr^{-1}
C. 15.5 yr^{-1}
D. 0.0647 yr^{-1}
E. 0.000967 yr^{-1}

38. Which type of atomic orbital has a shape resembling two dumbbells intersecting one another (or a 4-leaf clover shape)?

A. s
B. p
C. d
D. f
E. g

39. Which of these substances has the highest standard reduction potential?

A. Na^+
B. I_2
C. F_2
D. Ca^{2+}
E. $A\ell^{3+}$

40. In a standard Galvanic electrochemical cell, what is the purpose of a salt bridge?

A. It is needed to equalize charges in the two half reactions due to the movement of electrons.
B. It adds free energy to the system that increases the rate at which electrons move between half-cells.
C. It is needed to make sure that the two half-cells have the proper electrical charges.
D. It removes stray electrons from the system that might contribute to an electrical short circuit.
E. It keeps both electrodes properly saturated with ions for the most efficient production of electrons.