

Academic Challenge



EASTERN ILLINOIS UNIVERSITY

2023 Academic Challenge

CHEMISTRY TEST – REGIONAL

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!

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Periodic Table of the Elements

1													17	18			
IA													VIIA	VIIIA			
1 H 1.0079	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	1 H 1.0079	2 He 4.0026
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.990	12 Mg 24.305	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 ←	9 VIII B	10 →	11 IB	12 IIB	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.70	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc [97.91]	44 Ru 101.07	45 Rh 102.905	46 Pd 106.4	47 Ag 107.868	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.904	54 Xe 131.30
55 Cs 132.905	56 Ba 137.33	57-71 La	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.05	79 Au 196.966	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At [209.99]	86 Rn [222.02]
87 Fr [223.02]	88 Ra [226.03]	89-103 Ac	104 Rf [265.12]	105 Db [268.13]	106 Sg [271.13]	107 Bh [270]	108 Hs [277.15]	109 Mt [276.15]	110 Ds [281.16]	111 Rg [280.16]	112 Cn [285.17]	113 Nh [284.18]	114 Fl [289.19]	115 Mc [288.19]	116 Lv [293]	117 Ts [294]	118 Og [294]

	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Lanthanides	La 138.905	Ce 140.12	Pr 140.907	Nd 144.24	Pm [145]	Sm 150.4	Eu 151.96	Gd 157.25	Tb 158.925	Dy 162.50	Ho 164.930	Er 167.26	Tm 168.934	Yb 173.04	Lu 174.967
Actinides	89 Ac [277.03]	90 Th 232.038	91 Pa 231.035	92 U 238.029	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]	103 Lr [262.11]

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

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

$$P_{\text{solvent}} = X_{\text{solvent}} \cdot P_{\text{solvent}}^{\circ}$$

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

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

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

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

$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

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

$$\Delta G^{\circ} = -nF\epsilon^{\circ}$$

$$\Pi = MRT$$

$$F = 96485 \frac{\text{C}}{\text{mol}}$$

$$R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$$

$$1.0 \text{ kg} = 2.2 \text{ lb}$$

$$1.0 \text{ in} = 2.54 \text{ cm}$$

$$1 \text{ lb} = 453.59 \text{ g}$$

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

$$h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s}$$

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

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

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

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

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

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

$$\text{pOH} = -\log[\text{OH}^-]$$

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

$$E_{\text{cell}}^{\circ} = E_{\text{red}}^{\circ} + E_{\text{ox}}^{\circ}$$

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

$$c = \lambda\nu$$

$$\Delta E = h$$

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

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

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

$$1 \text{ atm} = 101,325 \text{ Pa} = 1.01325 \text{ bar}$$

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

$$\lambda = \frac{h}{m \times v}$$

Assume all gases behave ideally unless specifically told to do otherwise

Assume all solutions are aqueous and at 25 °C unless specifically told otherwise

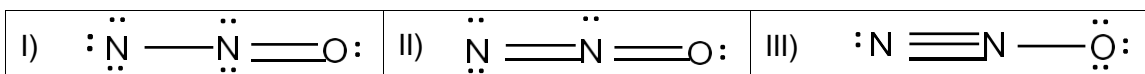
Assume all gases are at STP unless specifically told otherwise

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

WYSE – Academic Challenge
Chemistry Test (Regional) – 2023

1. Consider the following liquids and their respective densities: pentane, $d = 0.626 \text{ g/mL}$; carbon tetrachloride, $d = 1.88 \text{ g/mL}$; diiodomethane, $d = 3.33 \text{ g/mL}$; mercury, $d = 13.7 \text{ g/mL}$. If equal masses of each liquid are compared, which liquid occupies the largest volume?
 - A. pentane
 - B. carbon tetrachloride
 - C. diiodomethane
 - D. mercury
 - E. all occupy the same volume
2. What is the correct chemical formula for bromous acid?
 - A. HBr
 - B. HBrO
 - C. HBrO₂
 - D. HBrO₃
 - E. HBrO₄
3. Shown below are three possible Lewis structures for nitrous oxide, N₂O.



How many of these are valid Lewis structure(s)?

- A. I
 - B. II
 - C. III
 - D. I and II
 - E. II and III
4. The specific heat of water is $4.18 \text{ J/(g}\cdot\text{°C)}$; and the specific heat of copper is $0.382 \text{ J/(g}\cdot\text{°C)}$. Water _____ heat compared to copper when equal masses of water and copper both initially at 75 °C cool down to 25 °C .
 - A. absorbs less
 - B. releases less
 - C. absorbs more
 - D. releases more
 - E. absorbs the same amount

5. Place the following molecules in decreasing order of intermolecular forces.

HF H₂ CO₂

- A. CO₂ > H₂ > HF
B. H₂ > CO₂ > HF
C. HF > CO₂ > H₂
D. CO₂ > HF > H₂
E. None of the choices
6. How many of the following substances are acidic?
- I. pH = 5.9
II. pOH = 12
III. [H⁺] = 1.2 x 10⁻⁸ M
IV. pH = 9.4
V. [H⁺] = 8.1 x 10⁻³ M
VI. [OH⁻] = 7.5 x 10⁻⁵ M
- A. 1
B. 2
C. 3
D. 4
E. 5
7. Which of the following statements is true about a gas in a container at a temperature of 25 °C and a pressure of 1 atm according to the ideal gas law?
- A. the pressure exerted by the gas results from gas particles colliding with the container wall
B. the space inside the container is mostly empty
C. the gas can be compressed
D. the density of the gas is significantly smaller than its density in the solid or liquid states
E. all of the above
8. The atomic number of an element is 69. From this information it can be concluded that there are 69 _____ in the neutral atom
- A. electrons
B. neutrons
C. protons
D. electrons and neutrons
E. electrons and protons

9. Lead has a melting point of 328 °C and a normal boiling point of 1744 °C. In what state(s) does lead exist at 328 °C?

- A. solid
- B. liquid
- C. gas
- D. mixture of solid and liquid
- E. mixture of gas and liquid

10. Which formula is incorrect?

- A. NaCO_3
- B. BaSO_4
- C. Ca(OH)_2
- D. NH_4NO_3
- E. KI

11. How many of the following compounds have double or triple bonds in their structures?

O_2 H_2S Cl_2 CH_3OH NH_4OH

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

12. Choose **all** of the phase changes that are endothermic.

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

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

13. A 0.100 L sample of carbon monoxide, CO, is at a pressure of 0.905 atm and a temperature of 565 °C. What mass of CO does this sample contain? (R is $0.0821 \text{ L}\cdot\text{atm}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$.)

- A. 0.00131 g
- B. 0.0546 g
- C. 21.3 g
- D. 171 g
- E. 0.0368 g

14. Which of the following is not an acid?

- A. HNO_3
- B. NH_3
- C. CH_3COOH
- D. H_3PO_4
- E. H_2SO_4

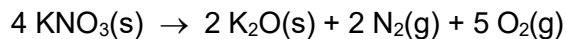
15. Which is the correct ground state electron configuration for Cr^{2+} ?

- A. $[\text{Ar}]4s^23d^2$
- B. $[\text{Ar}]3d^4$
- C. $[\text{Ar}]4s^13d^3$
- D. $[\text{Ar}]4s^23d^6$
- E. $[\text{Ar}]4s^13d^7$

16. What period 3 element would have the highest electron affinity?

- A. P
- B. Na
- C. Cl
- D. Mg
- E. Ar

17. Suppose 18.5 moles of oxygen gas are produced in the reaction below. What mass, in kg, of K_2O will also be produced? The molar mass of K_2O is 94.20 g/mol.



- A. $6.97 \times 10^5 \text{ kg}$
- B. 0.0463 kg
- C. 78.6 kg
- D. 0.697 kg
- E. $4.63 \times 10^4 \text{ kg}$

18. Two photons of light emit $7.275 \times 10^{-19} \text{ J}$ of energy. What is the wavelength of this light?

- A. 273.2 nm
- B. 546.0 nm
- C. $3.660 \times 10^{15} \text{ nm}$
- D. $1.831 \times 10^{15} \text{ nm}$
- E. $1.098 \times 10^{15} \text{ nm}$

19. Place the following species in the order of decreasing ionization energy.

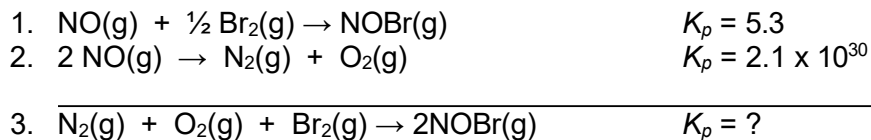
Cs Ca⁺ Ca

- A. Cs > Ca > Ca⁺
- B. Ca⁺ > Ca > Cs
- C. Ca > Ca⁺ > Cs
- D. Ca⁺ > Cs > Ca
- E. Cs > Ca⁺ > Ca

20. How many Ca atoms are found in 1.25 kg of Ca₃(PO₄)₂?

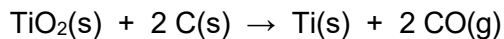
- A. 3
- B. 8.08×10^{23}
- C. 2.43×10^{24}
- D. 7.28×10^{24}
- E. 7.00×10^{29}

21. Using the data provided, determine the value of K_p for reaction 3.



- A. 1.3×10^{-29}
- B. 5.0×10^{-30}
- C. -2.1×10^{30}
- D. 5.9×10^{31}
- E. 1.1×10^{31}

22. The reaction below is carried out using 28.6 g of C and 88.2 g of TiO₂. If the percent yield is 80.9 %, determine the actual yield of titanium.



- A. 42.8 g
- B. 52.9 g
- C. 57.0 g
- D. 2.1 g
- E. 4.1 g

23. A student prepared an aqueous potassium bromide solution at a concentration of 0.811 *m*. Calculate the mass percent of the solute.

- A. 91.20 %
- B. 9.65 %
- C. 50.00 %
- D. 90.35 %
- E. 8.80 %

24. Choose the orbital diagram that represents the ground state of O^{2-} .

- A. $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow\uparrow\downarrow\uparrow\downarrow$
1s 2s 2p
- B. $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$ _____
1s 2s 2p
- C. $\uparrow\downarrow$ $\uparrow\downarrow$ \uparrow \uparrow _____
1s 2s 2p
- D. \uparrow $\uparrow\downarrow$ $\uparrow\downarrow$ \uparrow _____
1s 2s 2p
- E. $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$ \uparrow _____
1s 2s 2p

25. Which of the following types of electromagnetic radiation are capable of damaging biological tissue?

- (I) x-rays (II) infrared light (III) gamma rays (IV) microwaves

- A. I and II
- B. II and IV
- C. I and III
- D. II and III
- E. I, II, III, and IV

26. Which statement below best describes the solubility of a gas in water?

- A. Solubility is inversely proportional to pressure and directly proportional to temperature.
- B. Solubility is inversely proportional to pressure and temperature.
- C. Solubility is not dependent on either temperature or pressure.
- D. Solubility is directly proportional to pressure and temperature.
- E. Solubility is directly proportional to pressure and inversely proportional to temperature.

27. Intravenous saline fluids given in a hospital are usually 0.9 % m/v sodium chloride. A laboratory technician inadvertently prepared a saline solution at 1.1 % m/v. Which of the following statements would be true?

- A. The solution is hyposmotic and has a higher osmotic pressure than normal.
- B. The solution is hyperosmotic and has a lower osmotic pressure than normal.
- C. The solution is hyposmotic and has a lower osmotic pressure than normal.
- D. The solution is hyperosmotic and has a higher osmotic pressure than normal.
- E. The solution is isosmotic.

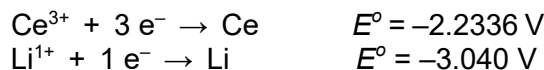
28. Compound A decomposes to form compound B. When $[A]^{-1}$ is plotted versus time, a straight-line results. What is the rate law?

- A. rate = $k[A]^1$
- B. rate = $k[A]^2$
- C. rate = k
- D. rate = $k[A]^{-1}$
- E. More information is necessary.

29. Calculate the molar solubility of MgF_2 in pure water. The K_{sp} of MgF_2 is 8.0×10^{-8} .

- A. $2.7 \times 10^{-3} M$
- B. $3.4 \times 10^{-3} M$
- C. $1.4 \times 10^{-4} M$
- D. $2.8 \times 10^{-4} M$
- E. $4.3 \times 10^{-3} M$

30. Using the half-reactions below, identify the strongest reducing agent.

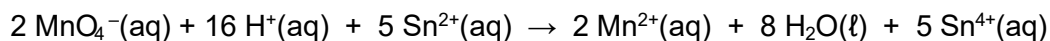


- A. Ce
- B. Ce^{3+}
- C. Li
- D. Li^{1+}
- E. None of these are reducing agents.

31. The quantum mechanical principle stating that one cannot know or observe both the velocity and the exact position of an electron in an atom is known as the _____.

- A. Aufbau Principle
- B. Pauli Exclusion Principle
- C. Hund's Rule
- D. Heisenberg Uncertainty Principle
- E. Hess's Law

32. In the redox reaction below, the oxidation number of manganese changes from _____ to _____.



- A. -1, +4
- B. +2, +4
- C. -1, +2
- D. +3, +2
- E. +7, +2

33. Given the following five prefixes used in metric measurement, what is the order of increasing quantitative values?

c (centi), k (kilo), m (milli), n (nano), d (deci)

- A. c, d, n, m, k
- B. n, m, c, d, k
- C. k, d, n, c, m
- D. k, n, m, d, c
- E. c, n, m, d, k

34. What is the number of significant figures in the quantity of 0.001350 mL?

- A. 3
- B. 4
- C. 5
- D. 6
- E. 7

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

- A. NH_3
- B. S_4
- C. Se^{2-}
- D. $\text{C}_4\text{H}_8\text{O}_4$
- E. O_2^{2-}

36. How many **total** atoms are represented in the chemical formula of $\text{BaSO}_4 \cdot 5\text{H}_2\text{O}$?

- A. 6
- B. 7
- C. 16
- D. 17
- E. 21

37. A hydrocarbon with a molar mass of 168 g/mol is known to contain 12 atoms of carbon per molecule. What is the empirical formula for this hydrocarbon?
- A. CH₂
 - B. CH
 - C. C₂H
 - D. CH₄
 - E. C₄H
38. The value of the amount expressed in 3.54×10^{-4} is the same as:
- A. 0.0000354
 - B. 0.0354
 - C. 354
 - D. 0.000354
 - E. 35,400
39. Which of the following have the same number of **total** electrons?
- A. Cl⁻, S²⁻, Na⁺
 - B. P⁵⁺, Xe, O²⁻
 - C. P³⁻, S²⁻, Ar
 - D. I⁻, Se²⁻, Ar
 - E. N³⁻, B³⁺, He
40. What is the mass percent of oxygen in calcium phosphate Ca₃(PO₄)₂. Molar Mass of Ca₃(PO₄)₂ is 310 g/mol.
- A. 41%
 - B. 46%
 - C. 31%
 - D. 35%
 - E. 39%

