



2012 Academic Challenge

CHEMISTRY TEST - REGIONAL

This Test Consists of 40 Questions

Chemistry Test Production Team

Doug Mulford, Emory University – Author/Team Leader

Tracy Morkin, Emory University – Author

Nancy Carter Dopke, Alma College – Reviewer

Mary Weaver, WYSE – Coordinator of Test Production

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. Only one oval should be marked to answer each question. Multiple ovals will automatically be graded as incorrect answers.

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!

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Periodic Table of the Elements

1A												8A																							
1	H											2	He																						
	1.008												4.003																						
2A												7A																							
3	Li	4	Be											9	F																				
	6.941		9.012												19.00																				
11	Na	12	Mg											17	Cl																				
	22.99		24.31												35.45																				
19	K	20	Ca	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr
	39.10		40.08		44.96		47.88		50.94		52.00		54.94		55.85		58.93		58.69		63.55		65.38		69.72		72.59		74.92		78.96		79.90		83.80
37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
	85.47		87.62		88.91		91.22		92.91		95.94		(98)		101.1		102.9		106.4		107.9		112.4		114.8		118.7		121.8		127.6		126.9		131.3
55	Cs	56	Ba	57	La*	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn
	132.9		137.3		138.9		178.5		180.9		183.9		186.2		190.2		192.2		195.1		197.0		200.6		204.4		207.2		209.0		(209)		(210)		(222)
87	Fr	88	Ra	89	Ac**	104	Unq	105	Unp	106	Unh	107	Uns	108	Uno	109	Une																		
	(223)		226		(227)																														

*Lanthanides	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu
	140.1	140.9	140.9	144.2	(145)	150.4	152.0	157.3	157.3	158.9	162.5	164.9	164.9	167.3	168.9	167.3	100	100	99	99	100	100	101	101	102	102	103	103
**Actinides	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr
	232.0	(231)	(231)	238.0	(237)	(244)	(243)	(247)	(247)	(247)	(251)	(252)	(252)	(257)	(257)	(258)	(257)	(257)	(252)	(252)	(257)	(257)	(258)	(259)	(259)	(260)	(260)	(260)

Potentially Useful Information

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

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

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

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

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

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

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

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

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

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

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

$$R = 0.08206 \text{ L atm/mol K}; 8.3145 \text{ J/mol K}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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) – 2012

1. What volume of “physiological saline” (i.e. 0.54 M NaCl) can be prepared from the dilution of 100.0 mL of 6.0 M NaCl?
A) 1.1 L B) 910 mL C) 95 mL D) 540 mL E) 1.9 L
2. Which correctly represents the species present when Na_2CO_3 dissolves in water?
A) Na^{2+} , CO_3^{2-}
B) Na_2 , CO_3
C) Na^+ , CO_3^{2-}
D) Na^{2+} , C^{4+} , O^{2-}
E) Na_2O , CO_2
3. Which group of ions can exist together in water solution in moderate concentration (i.e. minimal precipitation)?
A) Ba^{2+} , NO_3^- , K^+ , CO_3^{2-}
B) Ba^{2+} , Cl^- , K^+ , SO_4^{2-}
C) Ba^{2+} , Cl^- , K^+ , NO_3^-
D) Ag^+ , NO_3^- , K^+ , Cl^-
E) Pb^{2+} , NO_3^- , K^+ , Cl^-
4. A solution has a pH of 4.48. What is the $[\text{OH}^-]$ for this solution?
A) 3.0×10^{-11}
B) 3.0×10^{-10}
C) 3.0×10^{-9}
D) 3.3×10^{-5}
E) 3.3×10^{-4}
5. Atoms X, Y, Z, and R have the following nuclear compositions:
$${}_{186}^{410}\text{X} \quad {}_{183}^{410}\text{Y} \quad {}_{186}^{412}\text{Z} \quad {}_{185}^{412}\text{R}$$

Which two are isotopes?
A) X & Y B) X & Z C) Y & R D) Z & R E) X & R
6. Which of the following chemical reactions is a redox reaction?
A) $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$
B) $\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + 2\text{H}_2\text{O}$
C) $\text{AgNO}_3 + \text{KI} \rightarrow \text{AgI} + \text{KNO}_3$
D) $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$
E) $\text{CaO} + \text{SO}_3 \rightarrow \text{CaSO}_4$

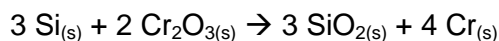
7. The specific heat of graphite is $0.710 \text{ J/}^\circ\text{C}\cdot\text{g}$. How much heat is required to raise the temperature of 75.0 kg of graphite from 294 K to 348 K ?

- A) $2.87 \times 10^3 \text{ J}$
 B) $1.74 \times 10^7 \text{ J}$
 C) $1.74 \times 10^4 \text{ J}$
 D) $2.87 \times 10^3 \text{ kJ}$
 E) $2.87 \times 10^6 \text{ kJ}$

8. A reaction between $\text{H}_2(\text{g})$ and $\text{CO}(\text{g})$ is run to produce $\text{H}_2\text{CO}(\text{g})$ in a 10.0 L vessel. The amounts of each reactant and product at different times are given in the table below. At which point does equilibrium first occur?

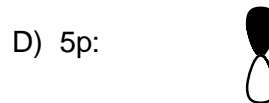
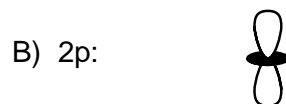
		Time			
		A	B	C	D
Moles	H_2	10.0	7.5	6.5	6.5
	CO	5.0	2.5	1.5	1.5
	H_2CO	0.0	2.5	3.5	3.5

- A) Point A
 B) Point B
 C) Point C
 D) Point D
 E) Equilibrium has not been reached
9. How many grams of SiO_2 can be made from 328 g of Cr_2O_3 based on the following reaction?



- A) 60.1 g
 B) 87.0 g
 C) 181 g
 D) 194 g
 E) 488 g
10. A compound contains 71.65% Cl, 24.27% C and 4.07% H by mass. What is the empirical formula?
- A) CH_2Cl B) $\text{C}_2\text{H}_4\text{Cl}_2$ C) C_2HCl D) CHCl_2 E) CHCl

11. Which of the following orbitals is not labeled correctly? Orbitals are not drawn to scale.



12. What is the Cl-Ge-Cl bond angle in GeCl_4 ?

- A) 180° B) 120° C) $<120^\circ$ D) 109.5° E) $<109.5^\circ$

13. From a consideration of the Lewis structure of the thiocyanate ion, SCN^- , in which the carbon has double bonds with both S and N, what are the formal charges on the sulfur, carbon, and nitrogen atoms, respectively?

- A) -1, 0, 0
 B) 0, 0, -1
 C) -1, +1, -1
 D) -2, +1, 0
 E) -2, 0, +1

14. Given the following rate law, what will happen to the rate if [A] is cut in half and [B] is doubled?

$$\text{rate} = k[\text{A}]^2[\text{B}]$$

- A) The rate will decrease by a factor of 2
 B) The rate will increase by a factor of 2
 C) The rate will decrease by a factor of 4
 D) The rate will increase by a factor of 4
 E) The rate will remain the same

15. The oxidation state of Cr in $\text{Cr}_2\text{O}_7^{2-}$ is:

- A) +4 B) +5 C) +6 D) +7 E) +8

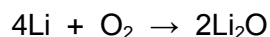
16. Potassium dichromate, $K_2Cr_2O_7$, is used in tanning leather, decorating porcelain, and water proofing fabrics. Calculate the number of chromium atoms in 78.82 g of $K_2Cr_2O_7$.
- A) 2.248×10^{24} Cr atoms
 B) 1.124×10^{24} Cr atoms
 C) 3.227×10^{23} Cr atoms
 D) 1.613×10^{23} Cr atoms
 E) 1.012×10^{23} Cr atoms
17. Carbon-14 and nitrogen-14 both have the same mass number, yet they are different elements. Which of the following statements is true?
- A) Carbon-14 and nitrogen-14 have the same number of neutrons and protons.
 B) Carbon-14 and nitrogen-14 have the same number of protons and electrons.
 C) Carbon-14 and nitrogen-14 have the same number of neutrons.
 D) Carbon-14 and nitrogen-14 have different numbers of protons, but the same number of neutrons.
 E) Carbon-14 and nitrogen-14 have different numbers of protons and neutrons.

18. An element has 5 stable isotopes. The mass and percentage of each are listed on the right. What is the element?

Atomic Mass (amu)	Percent Abundance (%)
89.9043	51.46%
90.9053	11.23%
91.9046	17.11%
93.9061	17.40%
95.9082	2.80%

- A) Nb
 B) Y
 C) Sr
 D) Zr
 E) Rb

19. Lithium (1.62 g) is reacted with 6.00 g oxygen. Which of these reactants is the limiting reagent and how much product will be formed.

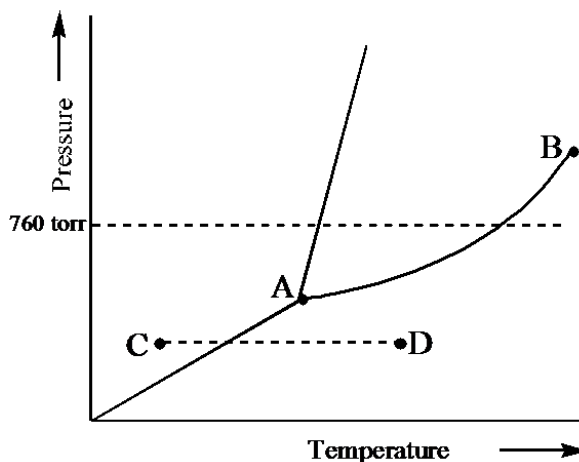


- A) Li limiting; 6.97 g product
 B) Li limiting; 3.50 g product
 C) O_2 limiting; 5.60 g product
 D) O_2 limiting; 11.21 g product
 E) O_2 limiting; 1.87 g product
20. If an equal mass of each gas is put into a separate balloon, which will have the greatest volume? Assume that they are all the same temperature and pressure.
- A) He B) H_2 C) N_2 D) Ne E) O_2

21. A gas tank containing 1.15 moles of N_2 has a pressure of 2150 torr at a temperature of $25.0\text{ }^\circ\text{C}$. The valve on the tank is opened allowing some of the gas to escape. What is the new pressure in the tank when 0.480 moles of gas have escaped and the temperature has dropped to $18.5\text{ }^\circ\text{C}$?
- A) 878 torr
B) 1220 torr
C) 1280 torr
D) 927 torr
E) 664 torr
22. Several properties of isopropyl alcohol (also known as rubbing alcohol) are listed below. Which of 1-5 listed is/are chemical properties?
1. Colorless
2. Liquid at room temperature
3. Mixes with water
4. Flammable
5. Density = 0.79 g/mL
- A) Only 3
B) Only 4
C) 2, 3, 4,
D) 3, 5
E) 3, 4, 5
23. Which of the following represents the largest volume?
- A) 100,000 pL B) 10,000 μL C) 1000 nL D) 100 mL E) 1 cL
24. Which equation best represents the first ionization energy for C?
- A) $\text{C}(\text{g}) + \text{e}^- \rightarrow \text{C}^-(\text{g})$ $\Delta\text{H} = \text{negative}$
B) $\text{C}(\text{g}) \rightarrow \text{C}^+(\text{g}) + \text{e}^-$ $\Delta\text{H} = \text{negative}$
C) $\text{C}(\text{g}) + \text{e}^- \rightarrow \text{C}^-(\text{g})$ $\Delta\text{H} = \text{positive}$
D) $\text{C}(\text{g}) \rightarrow \text{C}^+(\text{g}) + \text{e}^-$ $\Delta\text{H} = \text{positive}$
E) $\text{C}^+(\text{g}) \rightarrow \text{C}^{2+}(\text{g}) + \text{e}^-$ $\Delta\text{H} = \text{positive}$
25. Which of the following atoms is expected to have the smallest radius?
- A) Ba B) Kr C) Se D) Sn E) Cr
26. The density of mercury, the only metal to exist as a liquid at room temperature, is 13.6 g/cm^3 . What is that density in pounds per cubic inch?
- A) $1.83 \times 10^{-3}\text{ lb/in}^3$
B) 0.0760 lb/in^3
C) 0.491 lb/in^3
D) 376 lb/in^3
E) 849 lb/in^3

27. If, as a pioneer, you wished to warm your room by taking an object heated to 100 °C on top of a pot-bellied stove into it, which of the following 15-pound objects would be the best choice to warm up the cold room the most? The specific heat capacity for each substance is given in parentheses in $\text{J K}^{-1}\text{g}^{-1}$. Iron (0.45), zinc (0.090), copper (0.387), granite (0.79), gold (0.129)
- A) Iron B) zinc C) copper D) granite E) gold
28. Which one of the following equations correctly represents positron decay of ${}^{40}_{19}\text{K}$?
- A) ${}^{40}_{19}\text{K} \rightarrow {}^{36}_{17}\text{Cl} + {}^4_2\text{He}$
 B) ${}^{40}_{19}\text{K} + {}^0_{-1}\text{e} \rightarrow {}^{40}_{18}\text{Ar}$
 C) ${}^{40}_{19}\text{K} + {}^0_1\text{e} \rightarrow {}^{40}_{20}\text{Ca}$
 D) ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{20}\text{Ca} + {}^0_{-1}\beta$
 E) ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{18}\text{Ar} + {}^0_1\beta$
29. Which of the following ions contains unpaired electrons?
- A) V^{3+} B) Cd^{2+} C) Ti^{4+} D) Sn^{2+} E) Zn^{2+}
30. What is the name of CaI_2 ?
- A) calcium diiodide
 B) calcium(I) iodide
 C) calcium(II) iodide
 D) calcium iodide
 E) calcium(II) diiodide
31. $\text{NOBr}(\text{g})$ decomposes to give $\text{NO}(\text{g})$ and $\text{Br}_2(\text{l})$. What is the **correct** equilibrium constant expression for this reaction?
- A) $\frac{[\text{NO}]^2}{[\text{NOBr}]^2}$
 B) $\frac{[\text{NOBr}]}{[\text{NO}]}$
 C) $\frac{[\text{NO}][\text{Br}_2]}{[\text{NOBr}]}$
 D) $\frac{[\text{NO}]^2[\text{Br}_2]}{[\text{NOBr}]^2}$
 E) $\frac{[\text{NOBr}]^2}{[\text{NO}]^2[\text{Br}_2]^2}$

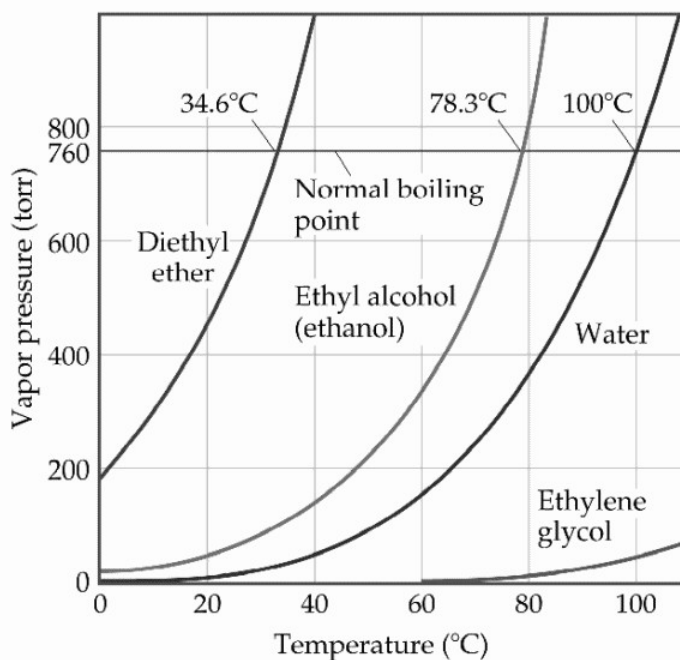
32. What is the purpose of the salt bridge in a voltaic cell?
- to maintain electrical neutrality in the half-cells via migration of ions.
 - to provide a source of ions to react at the anode and cathode.
 - to provide oxygen to facilitate oxidation at the anode.
 - to provide a means for electrons to travel from the anode to the cathode.
 - to provide a means for electrons to travel from the cathode to the anode.
33. Examine the phase diagram for the substance Illinoisium (Im) and select the correct statement.



- Im(s) has a lower density than Im(l).
 - The triple point for Im is at a higher temperature than the melting point for Im.
 - Im changes from a solid to a liquid as one follows the line from C to D.
 - Im changes from a liquid to a gas as one follows the line from C to D.
 - Point B represents the critical temperature and pressure for Im.
34. Two successive reactions, $D \rightarrow E$ and $E \rightarrow F$, have yields of 48% and 73%, respectively. What is the overall percent yield for conversion of D to F?
- 1.3%
 - 25%
 - 35%
 - 48%
 - 73%
35. Which of the following will be a buffer when dissolved in 1.0 L of water?
- 0.1 mol NaOH and 0.2 mol HCl
 - 0.1 mol HBr and 0.1 mol NaOH
 - 0.4 mol NH_3 and 0.2 mol HCl
 - 0.3 mol KCl and 0.3 mol HCl
 - 0.2 mol CH_3COOH and 0.4 mol NaOH
36. Which of the following acids has the lowest pH?
- 0.1 M HBO $K_a = 3.71 \times 10^{-3}$
 - 0.1 M HNO $K_a = 7.24 \times 10^{-4}$
 - 0.1 M HA $K_a = 2.81 \times 10^{-5}$
 - 0.1 M HMO $K_a = 5.89 \times 10^{-9}$
 - 0.1 M HST $K_a = 1.29 \times 10^{-12}$

37. Based on the figure below what is the boiling point of diethyl ether under an external pressure of 1.32 atm?

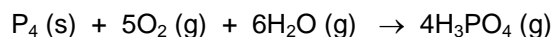
- A) 0 °C
 B) 10 °C
 C) 20 °C
 D) 30 °C
 E) 40 °C



38. The correct formula for lead(IV) oxide is:

- A) PbO
 B) PbO₂
 C) PbO₄
 D) Pb₄O
 E) Pb₄O₂

39. What is the minimum amount of phosphorus (P₄) needed to prepare 125 g of phosphoric acid?



- A) 9.88 g B) 24.3 g C) 39.5 g D) 97.2 g E) 124 g
40. Which of the following statements about kinetic molecular theory is **incorrect**?
- A) The average kinetic energy of gas molecules is proportional to their absolute temperature.
 B) All the molecules of a gas at a given temperature have the same kinetic energy.
 C) The volume of the gas molecules is negligible in comparison to the total volume the gas occupies.
 D) The collisions of molecules in an ideal gas are considered to be elastic.
 E) The velocity of an individual gas molecule is proportional to its molecular weight.