First Year High School Chemistry Contest

sponsored by

The Illinois Heartland Section of the American Chemical Society

and

**The Department of Chemistry at Illinois State University and
the Center for Mathematics, Science & Technology (CeMaST)**

Name:_____   Grade:_____

Home phone:_____   E-mail:_____

High school:_____   Teacher:_____

1. Do not start the exam until instructed to do so.

2. There is no talking or sharing of any materials. All cell phones should be shut off during the examination.

3. You have 80 minutes to complete this exam that features 50 questions and 2 challenge tie-breaker questions.

4. Mark all answers in pencil on the scan-tron sheet that has been provided. Be sure to make all erasures complete. There is no penalty for guessing at an answer.

5. Once you complete the 40 questions, then complete the challenge tie-breaker questions **101** and **102**. These multiple choice questions should be completed on the back of the scan-tron sheet.

6. You may use this exam booklet for scratch paper. Give this exam packet and scantron to the proctor who is closest to your seat.

7. Once you have completed the exam, you may turn in your exam. You may leave the examination area. You are asked to not re-enter until the exam is done.

Periodic Table of the Elements

IA 1																	VIIIA 18
1 **H** 1.01	IIA 2											IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											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	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	VIII B 8	9	10	IB 11	IIB 12	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** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	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** (99)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Ds** (271)	111 --- (272)	112 --- (277)		114 --- (285)		116 --- (289)		

Lanthanides	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (147)	62 **Sm** 150.36	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
Actinides	90 **Th** 232.04	91 **Pa** (231)	92 **U** 238.03	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)

Useful equations and constants

N = Avogrado's number = 6.02×10^{23} particles/mol

R = 0.08206 (L atm)/(mol K) = 8.314 J/(mol K)

$c = 3.00 \times 10^8$ m/s

1 atm = 760 torr = 1.01325×10^5 Pa

1.00 lb = 454 grams

$$PV = nRT$$

$$\ln[A] = -kt + \ln[A]_0$$

$$K = {}^{o}C + 273.15$$

$$pH = -\log[H^+]$$

$$pOH = -\log[OH^-]$$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G^{\circ} = -RT \ln K$$

$$q = C \times m \times \Delta T$$

$$\lambda = \frac{h}{mv}$$

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

$$\frac{1}{\lambda} = 1.096776 \times 10^7 / m \left(\frac{1}{n_a^2} - \frac{1}{n_b^2} \right)$$

$$\Delta E \text{ (J)} = c^2 \Delta m$$

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Identify the choice that best completes the statement or answers the question.

1. The symbol for the element sodium is_____.

A. S
B. So
C. Sm
D. Na
E. Sn

2. The correct answer for the addition 56.234 + 0.0021 g is: (considering significant figures)

A. 56 g
B. 56.24 g
C. 56.2361 g
D. 56.236 g
E. 56.255 g

3. The number of neutrons in an atom of uranium-235 is:

A. 235
B. 92
C. 327
D. 143
E. insufficient information given

4. The isotope symbol for an ion that has 11 protons, 12 neutrons, and 10 electrons is:

A. $_{11}^{12}\text{Na}$

B. $_{11}^{12}\text{Na}^{+}$

C. $_{11}^{23}\text{Na}^{+}$

D. $_{11}^{23}\text{Na}$

E. $_{12}^{23}\text{Mg}^{2+}$

5. Rank the boiling points of the following compounds from lowest to highest:
$C_{12}H_{22}O_{11}$ (sucrose), O_2, NaF

A. $C_{12}H_{22}O_{11}$ (sucrose), O_2, NaF
B. O_2, NaF, $C_{12}H_{22}O_{11}$ (sucrose)
C. O_2, $C_{12}H_{22}O_{11}$ (sucrose), NaF
D. NaF, O_2, $C_{12}H_{22}O_{11}$ (sucrose)
E. NaF, $C_{12}H_{22}O_{11}$ (sucrose), O_2

6. The formula for the permanganate ion is:

A. MnO_4^-
B. MnO_2^{2-}
C. MnO_3^-
D. MnO_3^{2-}
E. MnO_4^{2-}

7. How many carbon atoms are there in 0.50 mole of CO_2?

A. 0.50
B. 1.50
C. 3.0×10^{23}
D. 9.0×10^{23}
E. 8.3×10^{25}

8. Rank the following in order of increasing mass: 1.0 mole of SF_4, 0.50 mole of H_2S, 0.20 mole of Cu, and 0.10 mole of Pb.

A. $Pb < Cu < H_2S < SF_4$
B. $Cu < H_2S < Pb < SF_4$
C. $Pb < Cu < SF_4 < H_2S$
D. $Cu < H_2S < SF_4 < Pb$
E. $SF_4 < H_2S < Cu < Pb$

9. Balance the following skeletal equation: $C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$.

A. $C_3H_8(g) + O_2(g) \rightarrow 3CO_2(g) + 2H_2O(g)$
B. $C_3H_8(g) + O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
C. $C_3H_8(g) + 3O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
D. $C_3H_8(g) + 4O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
E. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

10. When aqueous solutions of sodium chloride and silver nitrate are mixed, a double-displacement reaction occurs. What is the balanced equation for the reaction?

A. $NaCl(aq) + AgNO_3(aq) \rightarrow Na(s) + AgNO_3Cl(aq)$
B. $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(aq)$
C. $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$
D. $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + ClAg(s)$
E. $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + 3AgCl(s)$

11. Phosphine, PH_3, a reactive and poisonous compound, reacts with oxygen as follows:
$$4PH_3(g) + 8O_2(g) \rightarrow P_4O_{10}(s) + 6H_2O(g)$$
If 9.2 moles of phosphine react with sufficient oxygen, how many moles of P_4O_{10} will be formed?
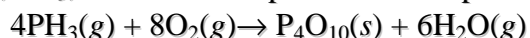
A. 4.0 moles
B. 9.2 moles
C. 37 moles
D. 2.3 moles
E. 6.0 moles

12. Phosphorus trichloride can be made by the reaction:
$$P_4(s) + 6Cl_2(g) \rightarrow 4PCl_3(l)$$
What is the maximum amount of phosphorus trichloride that can be formed if 15 molecules of P_4 react with 42 molecules of chlorine?
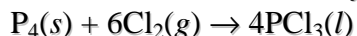
A. 4 molecules
B. 12 molecules
C. 24 molecules
D. 28 molecules
E. 57 molecules

13. Aluminum metal reacts with sulfuric acid according to the equation:

$$2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(s) + 3H_2(g)$$
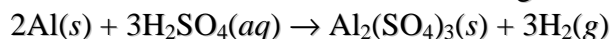
If 10.0 g of aluminum reacts with excess sulfuric acid, and 54.2 g of $Al_2(SO_4)_3$ are collected, what is the percent yield for the reaction?

A. 63.4%
B. 85.5%
C. 117%
D. 47.1%
E. not enough information given

14. If an equal quantity of heat is transferred to 10.0 g samples of liquid water (C = 4.184 J/g°C), concrete (C = 0.88 J/g°C), asphalt (C = 0.920 J/g°C), glass (C = 0.84 J/g°C), and iron (C = 0.448 J/g°C), rank the final temperatures of the samples from least to greatest.

A. iron < glass < concrete < asphalt < water
B. water < asphalt < concrete < glass < iron
C. asphalt < concrete < glass < iron < water
D. iron < concrete < glass < asphalt < water
E. water < concrete < asphalt < glass < iron

15. A 3.50 g sample of rice is burned in a bomb calorimeter containing 1980 g of water. The temperature of the water increases from 22.75°C to 28.88°C. How much heat, in joules, did the rice sample release when it burned? (C_{water} = 4.184 J/g°C)

A. 1.88×10^5 J
B. 2.39×10^5 J
C. 5.08×10^4 J
D. 3.33×10^2 J
E. 4.22×10^2 J

16. Rank the following types of electromagnetic radiation from shortest wavelength to longest wavelength: visible, ultraviolet, microwave, infrared, x-ray.

A. x-ray < visible < ultraviolet < infrared < microwave
B. x-ray < ultraviolet < visible < microwave < infrared
C. x-ray < ultraviolet < visible < infrared < microwave
D. infrared < microwave < ultraviolet < visible < x-ray
E. microwave < infrared < ultraviolet < visible < x-ray

17. List the following colors of visible light from shortest wavelength to longest wavelength: green, blue, yellow, red, violet.

A. red < yellow < green < blue < violet
B. violet < yellow < green < blue < red
C. blue < violet < green < red < yellow
D. violet < blue < green < yellow < red
E. yellow < red < green < violet < blue

18. A laser used in DVD players has a wavelength of 405 nm. What is the frequency of this light in hertz (s^{-1})?

A. $7.41 \times 10^5 \text{ s}^{-1}$
B. $7.41 \times 10^{14} \text{ s}^{-1}$
C. $1.35 \times 10^{-6} \text{ s}^{-1}$
D. $1.35 \times 10^{-13} \text{ s}^{-1}$
E. $1.22 \times 10^2 \text{ s}^{-1}$

19. Write the electron configuration for the element chlorine.

A. $1s^2 2s^2 2p^5$
B. $1s^2 2s^2 2p^6 3s^2 4p^5$
C. $1s^2 2s^2 2p^6 3s^2 3p^5$
D. $1s^2 2s^2 2p^6 3s^2 3p^6$
E. $1s^2 2s^2 2p^6 3s^2 4p^6$

20. The following orbital diagram corresponds to the element_____.

⇅ ⇅ ⇅ ⇅ ⇅ ⇅ ↑ ↑ ↑
1s 2s   2p   3s   3p
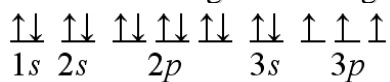
A. Al
B. Si
C. P
D. As
E. S
F. Cl

21. Rank the following elements in order of increasing ionization energy: Sr, He, Si, F

A. Sr < Si < He < F
B. F < Si <He < Sr
C. Sr < Si <F < He
D. Si < F <He < Sr
E. He < F < Sr < Si

22. The formula of the compound that would be formed when magnesium and fluorine react is:

A. MgF
B. Mg_2F
C. MgF_2
D. F_2Mg
E. FMg

23. Which of the following compounds is likely to have covalent bonds?

A. NaCl
B. LiF
C. CO
D. $CaBr_2$
E. MgO

24. Arrange the following bonds in order of increasing polarity: F-F, F-C, F-O, F-N

A. F-F < F-C < F-O < F-N
B. F-F < F-O < F-N < F-C
C. F-O < F-N < F-F < F-C
D. F-N < F-O < F-F < F-C
E. F-N < F-C < F-O < F-F

25. Identify the class of organic substance for the molecule H_3C-CH_3.

A. alkane
B. alkene
C. alcohol
D. amine
E. ester

26. Predict the molecular shape and give the approximate bond angles of the PCl_3 molecule.

A. linear, 180°
B. trigonal planar, 120°
C. tetrahedral, 109.5^o
D. trigonal pyramidal, 109.5^o
E. bent, 120°

27. Predict the molecular shape and give the approximate bond angles of the SO_2 molecule.

A. linear, 180°
B. trigonal planar, 120°
C. tetrahedral, 109.5^o
D. trigonal pyramidal, 109.5^o
E. bent, 120°

28. Which of the following molecules is polar?

A. BCl_3
B. NH_3
C. $SiCl_4$
D. CBr_4
E. $BeBr_2$

29. If the initial pressure of a 2.00 L gas sample is 2.50 atm, what will the pressure be if the volume is changed to 3.00 L at constant temperature?

A. 1.50 atm
B. 1.67 atm
C. 15.0 atm
D. 2.40 atm
E. 0.600 atm

30. Given a fixed amount of gas held at constant pressure, calculate the volume it would occupy if a 2.00 L sample were cooled from 60.0°C to 30.0°C.

A. 1.00 L
B. 4.00 L
C. 2.20 L
D. 0.455 L
E. 1.82 L

31. Calculate the number of moles in 55 g of N_2, and the volume that it would occupy at STP.

A. 2.0 mol, 45 L
B. 2.0 mol, 0.089 L
C. 1.5×10^3 mol, 67 L
D. 1.5×10^3 mol, 3.4×10^4 L
E. 3.9 mol, 88 L

32. Which of the following substances can participate in hydrogen bonding?

A. SiH_4
B. CH_2Cl_2
C. H_2O
D. PH_3
E. both H_2O and PH_3

33. Arrange the following substances in order of increasing boiling point: CH_3OH, CH_4, CH_3CH_2OH, $HOCH_2CH_2OH$

A. $CH_3OH < CH_4 < CH_3CH_2OH < HOCH_2CH_2OH$
B. $CH_4 < CH_3OH < CH_3CH_2OH < HOCH_2CH_2OH$
C. $CH_4 < CH_3OH < HOCH_2CH_2OH < CH_3CH_2OH$
D. $CH_3OH < CH_4 < HOCH_2CH_2OH < CH_3CH_2OH$
E. $HOCH_2CH_2OH < CH_3CH_2OH < CH_3OH < CH_4$

34. A solid substance has a high melting point, is hard, brittle, and conducts electricity when molten. This substance is probably a(n)_____ solid.

A. metallic
B. ionic
C. network
D. nonpolar molecular
E. polar molecular

35. Which of the following substances is a strong electrolyte?

A. CH_3CH_2OH
B. C_6H_6
C. KOH
D. SO_2
E. PCl_3

36. What is the percent-by-mass concentration of NaCl in a solution that is prepared by adding 14.0 g of NaCl to 75.0 g of water?

A. 61.0%
B. 15.7%
C. 18.7%
D. 24.0%
E. 5.36%

37. How many moles of HCl are contained in 75.0 mL of 2.00 M HCl?

A. 2.00 moles
B. 1.50×10^2 moles
C. 0.150 moles
D. 37.5 moles
E. 26.7 moles

38. A 150.0 g sample of ocean water contains 3.5 mg of mercury. How many parts per million of mercury are in the sample?

A. 15 ppm
B. 23 ppm
C. 2.4×10^2 ppm
D. 2.3×10^4 ppm
E. 43 ppm

39. How many moles of potassium iodide, KI, are required to precipitate all of the lead(II) ion from 50.0 mL of a 1.2 M $Pb(NO_3)_2$ solution? (First, write a balanced equation for the reaction.)

A. 0.12 mole
B. 0.060 mole
C. 0.24 mole
D. 0.030 mole
E. 0.048 mole

40. Select the correct equilibrium constant expression for the reaction:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$
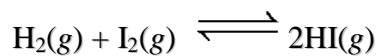
A. $K_{eq} = \dfrac{[HI]}{[H_2][I_2]}$

B. $K_{eq} = [HI]^2 [H_2][I_2]$

C. $K_{eq} = [HI]^2 + [H_2] + [I_2]$

D. $K_{eq} = \dfrac{[HI]^2}{[H_2][I_2]}$

E. $K_{eq} = \dfrac{[H_2][I_2]}{[HI]^2}$

41. Which equilibrium constant represents a reaction that is reactant favored?

A. $K_{eq} = 0.025$
B. $K_{eq} = 5.2$
C. $K_{eq} = 8.4 \times 10^{-5}$
D. $K_{eq} = 6.3 \times 10^5$
E. not enough information

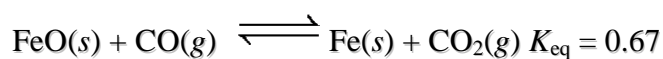42. Consider the following reaction at a specific temperature:

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$$
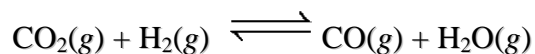
If $[CO_2] = 3.60\ M$, $[H_2] = 4.00\ M$, $[CO] = 1.18\ M$, and $[H_2O] = 2.40\ M$ at equilibrium, calculate the value of the equilibrium constant under these conditions.

A. 0.471
B. 0.197
C. 5.08
D. 2.12
E. 0.444

43. Consider the following reaction and its equilibrium constant:

$$FeO(s) + CO(g) \rightleftharpoons Fe(s) + CO_2(g)\ K_{eq} = 0.67$$

If the equilibrium concentration of CO is measured at $0.40\ M$, what is the equilibrium concentration of CO_2?

A. $0.40\ M$
B. $1.1\ M$
C. $0.67\ M$
D. $0.27\ M$
E. $1.7\ M$

44. The conjugate base of $H_2PO_4^-$ is:

A. HPO_4^{2-}
B. $H_2PO_3^-$
C. H_3PO_4
D. PO_4^{3-}
E. $H_2PO_4OH^-$

45. Calculate the pH of a solution that has $[OH^-] = 1.0 \times 10^{-6}\ M$.

A. pH = 1.00
B. pH = 7.00
C. pH = 6.00
D. pH = 8.00
E. pH = 14.00

46. Consider the following reaction:
$$Mg(s) + NiSO_4(aq) \rightarrow MgSO_4(aq) + Ni(s)$$
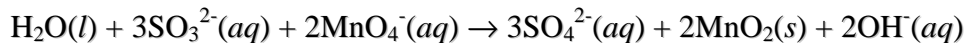Which of the following statements regarding this reaction is correct?
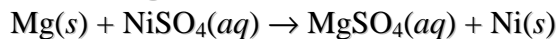
A. Each magnesium atom gains two electrons.
B. The sulfate ion is reduced.
C. Nickel ion is the oxidizing agent.
D. Magnesium is reduced.
E. Each nickel ion loses two electrons.

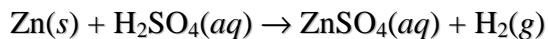47. Consider the reaction:
$$H_2O(l) + 3SO_3^{2-}(aq) + 2MnO_4^-(aq) \rightarrow 3SO_4^{2-}(aq) + 2MnO_2(s) + 2OH^-(aq)$$
Which species is reduced?

A. H_2O
B. SO_3^{2-}
C. MnO_4^-
D. SO_4^{2-}
E. MnO_2

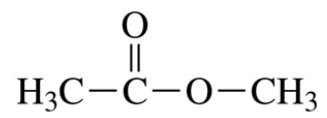48. Consider the reaction:
$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$
Which species is oxidized, and how many electrons are transferred per atom of zinc that reacts?

A. Zn, 2 electrons
B. H^+, 2 electrons
C. SO_4^{2-}, 4 electrons
D. Zn^{2+}, 4 electrons
E. H_2, 2 electrons

49. Gamma rays are:

A. high-energy electromagnetic radiation.
B. H nuclei.
C. electrons.
D. He nuclei.
E. positrons.

50.

$$H_3C-\overset{\overset{\displaystyle O}{\|}}{C}-O-CH_3$$

 To which class of compounds does the molecule shown in the figure belong?

A. ketone
B. aldehyde
C. alcohol
D. ester
E. carboxylic acid

ACS High School Chemistry Contest Key

1.D

2.D

3.D

4.C

5.C

6.A

7.C

8.B

9.E

10.C

11.D

12.D

13.B

14.B

15.C

16.C

17.D

18.B

19.C

20.C

21.C

22.C

23.C

24.B

25.A

26.D

27.E

28.B

29.B

30.E

31.A

32.C

33.B

34.B

35.C

36.B

37.C

38.B

39.A

40.D

41.C

42.B

43.D

44.A

45.D

46.C

47.C

48.A

49.A

50.D