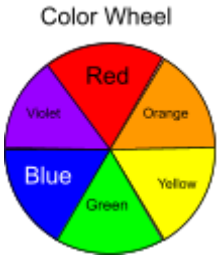
Section II: Chemistry

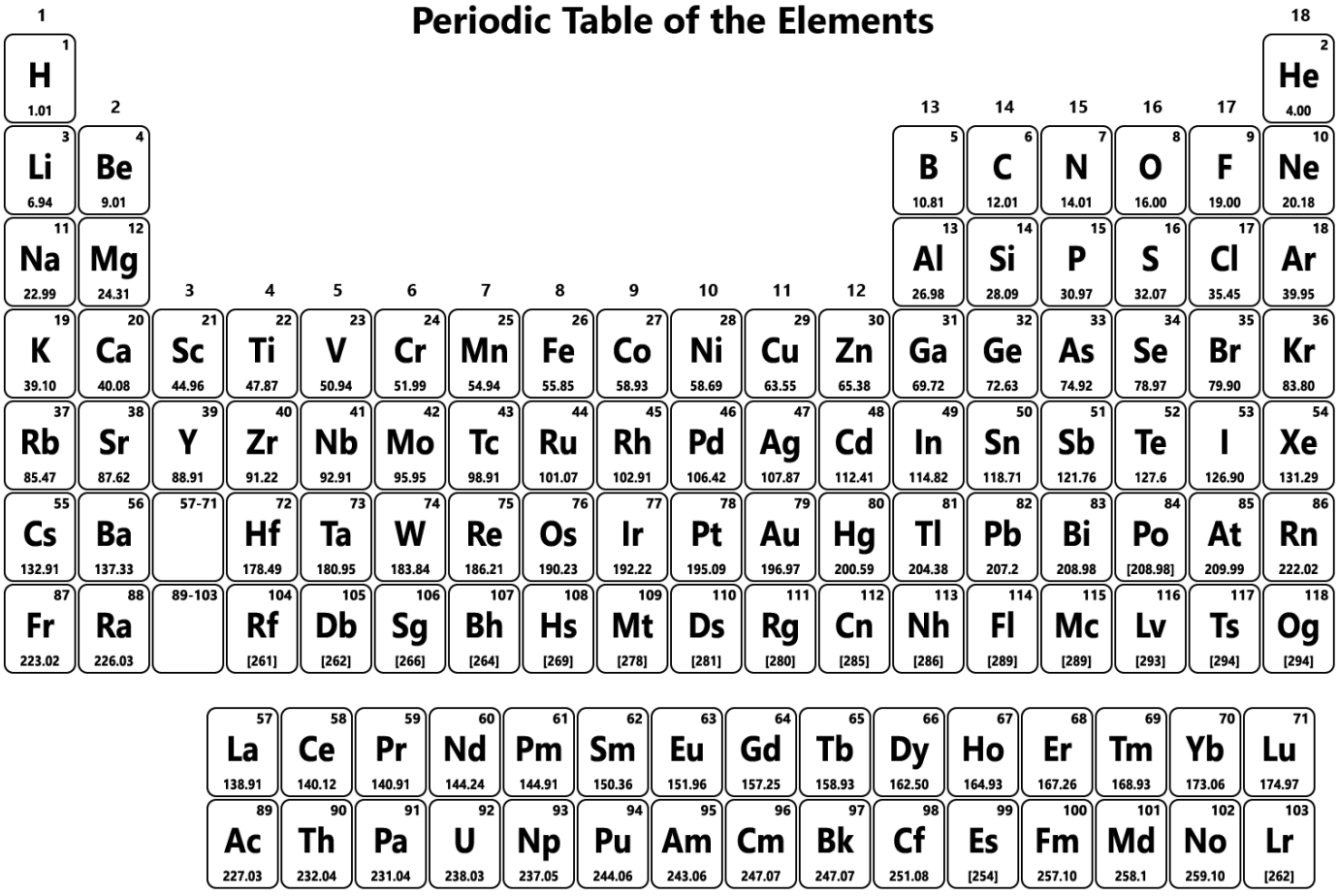
Suggested Time: 36 minutes
35 Questions

- For each of the following questions, select the **one** correct answer and fill in the corresponding bubble on the answer sheet. Bubbling in multiple answers per question will result in an automatic incorrect answer.
- You get 1 point for a correct answer, 0 points for a blank answer, and -0.25 points for an incorrect answer.
- You may move freely between this section and other sections.
- You should examine every question and not spend too much time on any one question, since the questions are all weighted equally and not arranged in order based on difficulty.

CONSTANTS:

$h = 6.626 \times 10^{-34}$ J · s
F = 96485 C/(mol e^-)
$c = 2.998 \times 10^8$ m/s
R = 8.314 J/(K · mol)
R = 0.08206 L · atm/(mol · K)





1. Organic compound **A** is sour-smelling, but it reacts with ethanol in the presence of sulfuric acid to form a sweet-smelling **B**. Compound **A** has a peak near 1700 cm^{-1} and a broad peak near 3300 cm^{-1} in its IR (infrared) spectrum. What functional group does compound **A** contain?
    a. Ether
    b. Ketone
    c. Carboxylic Acid
    d. Ester
    e. Thiol

2. You react 0.0200 Molar Reactant **C** with 5.0 M Sodium Hydroxide. The table below shows the concentration of Reactant **C** at different times.

Time since start of reaction (s)	Concentration of Reactant **C** (M)
0	0.0200
10	0.0137
20	0.0094
30	0.0064

    Determine the order of Reactant **C** in the rate-law of the examined reaction.
    a. 0th order
    b. ½ order
    c. 1st order
    d. 2nd order
    e. 3rd order

3. You are handed a block of pure metal with mass 647 g and volume 72.5 cm^3. You are told that the mystery metal composing the block has a unit cell side length of 361 pm (assume one of the cubic packing patterns of metal atoms in the unit cell). You can deduce that the mystery metal is:
    a. Nickel
    b. Zinc
    c. Copper
    d. Iron
    e. Manganese

4. I want to collect my crystallized final product after an organic synthesis reaction from the suspension it is in. Which apparatus should I use to separate my solid product from the solvents?

a.	
b.	
c.	
d.	
e.	

5. Which of the following compounds has the highest lattice energy?
    a. $BaSO_4$
    b. NaCl
    c. NaBr
    d. $BaCl_2$
    e. $CaSO_4$

6. The vapor pressure of water is 23.8 Torr at 25 ℃. A chemist dissolves 0.0200 g of NaCl in 12.0 g of liquid water. She then places the solution in an evacuated 2.00 L container at 25 ℃. Since the container is equipped with a movable piston, she expands the container until it has a volume of 20.0 L while keeping the temperature 25 ℃. What is the concentration of NaCl in this final solution?
(NOTE: 1 atm = 760 Torr = 760 mmHg)
    a. 1.71×10^{-4} M
    b. 2.67×10^{-2} M
    c. 2.85×10^{-2} M
    d. 2.97×10^{-2} M
    e. 5.94×10^{-2} M

7. You are trying to observe the beautiful purple flame produced by potassium salts. However, for some reason you can only see bright yellow flames. You suspect your sample is most likely contaminated with which of the following ions?
    a. Boron
    b. Sodium
    c. Strontium
    d. Lithium
    e. Calcium

8. John is attempting to determine the amount of Fe^{2+} in a solution **A** by titrating it with potassium permanganate ($KMnO_4$). John first standardizes the permanganate solution (determining the permanganate concentration) by using the permanganate solution to titrate a sample of oxalic acid of known concentration. Which of the following errors will result in John's answer of the Fe^{2+} concentration in solution **A** to be artificially high?
    a. The flask containing the oxalic acid for the standardization is wet before the pre-measured amount of oxalic acid is added.
    b. The buret containing the permanganate for the standardization was rinsed with water, but not permanganate before the buret was filled with permanganate.
    c. After adding the correct amount of solution **A** to the flask, John spilled some of the solution **A** in the flask prior to the second titration.
    d. Some of the Fe^{2+} in solution **A** converted to Fe^{3+} due to oxidation from the air prior to the titration.
    e. After measuring, the oxalic acid placed in the flask for the standardization is spilled slightly.

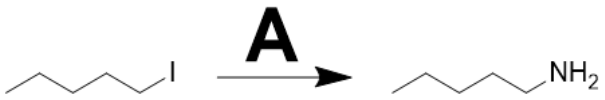
9. Adding 1 mol of which of the following compounds to water would result in the lowest pH?
    a. NaCl
    b. HNO_2
    c. HNO_3
    d. $FeCl_3$
    e. HF

10. I have a compound **Q** made of only carbon, hydrogen, and oxygen. I combust 26.35 g of the compound **Q** under excess oxygen and obtain as the combustion products 21.06 g of H_2O and 35.2 g CO_2. No other combustion products form. What is the empirical formula of compound **Q**?
    a. CH_2
    b. CH_2O
    c. CH_3
    d. CH_3O
    e. CH_3O_2

11. Which of the following compounds would be attracted to a magnetic field?
    I. O_2
    II. N_2
    III. OF
    IV. F_2

    a. I only
    b. I and II
    c. I and III
    d. III and IV
    e. All of the above

12. Select all possible reagents **A** that complete the following synthetic pathway producing the shown product as the major product. Assume that the total amount of added nitrogen containing reactants (NH_3, KN_3, $KH_2 + NH_3$) in each answer choice is not in excess relative to the alkyl iodide.



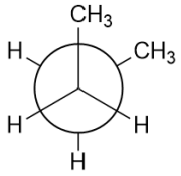
    I. NH_3 in THF
    II. 1) KN_3 2) PPh_3 3) H_2O
    III. KNH_2/NH_3

    a. I only
    b. II only
    c. III only
    d. I and II
    e. II and III

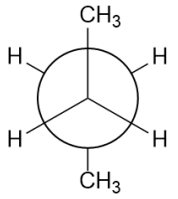
13. Which of the following molecules has the smallest bond angle X-C-X, where X are the peripheral atoms and C is the central atom?
    a. H_2O
    b. CH_4
    c. NH_3
    d. BH_3
    e. I_3^-

14. I am running a current of 3.0 A into a solution of silver nitrate using a piece of silver and a copper penny as the anode and cathode respectively. I am attempting to coat the copper penny in a layer of solid silver. How many seconds do I need to run the current for in order to add 0.54 g of silver to the penny?
    a. 80
    b. 160
    c. 180
    d. 320
    e. 480

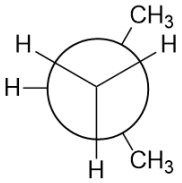
15. Which conformation of *n*-butane is most stable?
    a.



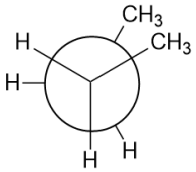
    b.



    c.



    d.



e. They are all the same stability

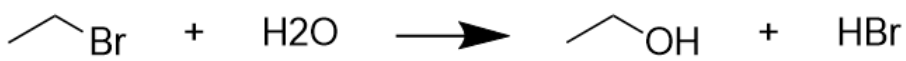
16. A mystery salt turns brick red when reacting with Ag^+. When dissolved in water, the solution turns yellow, but when acid is added the solution turns orange. Which ion is **most likely** present in the salt?
    a. CH_3COO^-
    b. Na^+
    c. V^{2+}
    d. CrO_4^{2-}
    e. S^{2-}

17. Which of the following can act as a reducing agent?
    a. Zn^{2+}
    b. Fe^{2+}
    c. K^+
    d. Ba^{2+}
    e. SO_4^{2-}

18. Given that the pKa of acetic acid is 4.76, what is the pH of a 500.0 mL solution of 2.00 M acetic acid after adding 50.0 mL of 1.50 M sodium hydroxide?
    a. 3.67
    b. 4.76
    c. 7.23
    d. 9.67
    e. 14.18

19. An organic compound is told to have the M peak at 121 m/z. The M+1 peak has 5.4% abundance relative to the M peak. The M+2 peak has 33% abundance relative to the M peak. What is the molecular formula of this compound?
    a. $C_6H_{14}O_2$
    b. $C_6H_{13}Cl$
    c. $C_6H_7N_3$
    d. $C_5H_{12}ClN$
    e. C_3H_5Br

20. Given the following bond dissociation enthalpies, what is the enthalpy of the reaction below?



Bond	Bond Dissociation Enthalpy (kJ/mol)	Bond	Bond Dissociation Enthalpy (kJ/mol)
C-C	368	C-Br	284
C-H	473	C-O	335
O-H	436	H-Br	366

a. -417 kJ/mol
b. -75 kJ/mol
c. -19 kJ/mol
d. 19 kJ/mol
e. 417 kJ/mol

21. A method of balancing oxidation-reduction reaction is using half-reactions, which treats the oxidation and the reduction as separately written processes. Which of the following transformations depicts a half-reaction of an oxidation process?
    a. $MnO_4^{-2} + H^+ \rightarrow Mn^{+2} + H_2O$;
    b. $Ag[(NH_3)_2] \rightarrow Ag^0\downarrow + NH_3$;
    c. $S_2O_8^{-2} \rightarrow SO_4^{-2}$;
    d. $BiO_3^- + H^+ \rightarrow Bi^{+3} + H_2O$;
    e. $S_2O_3^{-2} \rightarrow S_4O_6^{-2}$

22. The pair of cations, anions, or atoms which have a different electronic configuration are:
    a. Cl^- and Ti^{+4} ;
    b. C^{+4} and Li^+;
    c. S^{-2} and V^{+3};
    d. As^{-3} and Br^-;
    e. Ne and Mg^{+2}.

23. A reaction A → C is told to have rate constant 2.53 $M \cdot s^{-1}$. If I were to raise the concentration of A in solution from 0.257 M to 0.537 M, the new rate of reaction will be what product of the initial rate (e.g. 2 means the new rate is twice as quick)?
    a. 0.25
    b. 0.5
    c. 1
    d. 2
    e. 4

24. Luke is trying to titrate a dilute solution of Fe^{2+} ions with potassium permanganate. However, instead of forming a clear or pale yellow solution as he expected, he instead notices a brown precipitate. How could this precipitate formation affect his calculation of the Fe^{2+} concentration, and how could he fix the issue of the precipitate formation (and carry out the titration as he intended, forming a clear/pale yellow solution)?

	Effect of Brown Precipitate Formation on Calculated Fe^{2+} Concentration	**How to remove brown precipitate and carry out titration as intended?**
a.	Calculated concentration too high	Add Acid
b.	Calculated concentration too high	Add Base
c.	Calculated concentration too low	Add Acid
d.	Calculated concentration too low	Add Base
e.	Calculated concentration too low	Add oxidizing agent

25. Compound A follows a decay scheme shown below: A → B → C.
The rate constant of the A → B step is k_1, and the rate constant of the B → C step is k_2.
Assuming steady state, which of the following expressions below equals the rate of formation of C (in other words, $\frac{d[C]}{dt}$)?
    a. $k_1[A]$
    b. $k_2[A]$
    c. $k_1k_2[A]$
    d. $\frac{k_1+k_2}{k_1}[A]$
    e. $\frac{k_1+k_2}{2}[A]$

26. The K_{sp} of $CaSO_4$ 2.4 x 10^{-5}. I begin with a 0.003 M solution of $Ca(NO_3)_2$ in 10. mL of water. I slowly add a solution of 0.0025 M Na_2SO_4. How many mLs of Na_2SO_4 must be added before $CaSO_4$ begins to precipitate from solution?
    a. 63 mL
    b. 126 mL
    c. 154 mL
    d. 174 mL
    e. $CaSO_4$ will not precipitate, regardless of the mLs of Na_2SO_4 added.

27. When the following equation is balanced, what is the sum of the coefficients?

$$I_3^- + H_2C_2O_4 \rightarrow CO_2 + I^- + H^+$$

    a. 6
    b. 7
    c. 8
    d. 9
    e. 10

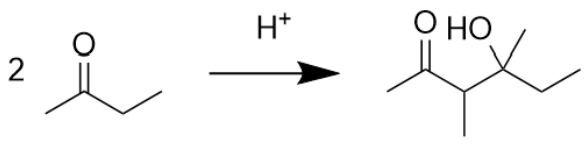
28. The ionization energy of an electron in a He^+ ion is 8.71×10^{-18} J. What is the longest wavelength of light able to promote an electron in Be^{3+} to an f orbital?
    a. 6.08 nm
    b. 9.23 nm
    c. 11.4 nm
    d. 22.8 nm
    e. 37.6 nm

29. Which of the following groups of ions can coexist in an aqueous solution in significant quantities without reacting with each other?
    a. K^+ , Cl^-, Al^{3+} , OH^-
    b. Ag^+ , NO_3^-, K^+ , Br^-
    c. Ba^{2+}, Br^-, Na^+ , SO_4^{2-}
    d. Na^+ , HSO_4^-, K^+ , HCO_3^-
    e. Ba^{2+}, Cl^-, Fe^{3+} , NO_3^-.

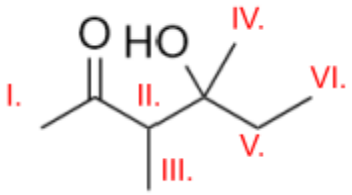
30. How many optically active compounds exist with the chemical formula $Cu[H_2NCH_2CH_2NH_2]Br_2Cl_2$?
    a. 0
    b. 2
    c. 4
    d. 6
    e. 8

31. Which element has the lowest ionization energy?
    a. Be
    b. B
    c. C
    d. N
    e. O

32. Consider the following reaction:



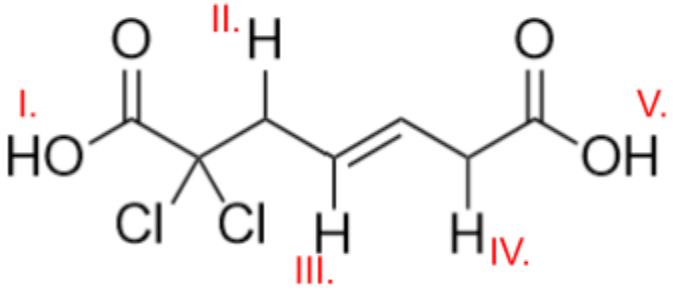
If the reaction was run in the presence of deuterium ions ($^2H^+$) instead of hydrogen ions ($^1H^+$), the hydrogen atoms bound to which highlighted carbons in the product will become invisible to ^1H NMR?



a. I and II only
b. II, III, VI only
c. I, II, V only
d. I, II, IV, V only
e. II, III, V only

33. Olivia is making a solution of dilute sulfuric acid (she is making 500 mLs of the diluted solution) from a stock (24 M) solution. After calculating how much water and how much acid she needs, what procedure should she follow to make the dilute solution?
    a. Use graduated cylinders to measure the appropriate amounts of acid and water, transfer both simultaneously to a 1000 mL erlenmeyer flask while gently swirling the flask.
    b. Use graduated cylinders to measure the appropriate amounts of acid and water, transfer both simultaneously to a 1000 mL beaker while gently swirling the beaker.
    c. Use graduated cylinders to measure the appropriate amounts of acid and water, transfer both simultaneously to a 500 mL volumetric flask while gently swirling the flask with the lid on.
    d. Use graduated cylinders to measure the appropriate amounts of acid, transfer the acid to a 500 mL volumetric flask, then fill the flask with water to the line, then gently swirl the flask with the lid on.
    e. Use graduated cylinders to measure the appropriate amounts of acid, transfer the acid into a 500 mL volumetric flask with a moderate amount of water already in it, then swirl gently and top off with water. Then gently swirl the flask with the lid on.

34. If the following compound is treated with base, which of the hydrogen atoms below will be deprotonated first by the base?



a. I
b. II
c. III
d. IV
e. V

35. Which of these isotopes is most likely to undergo beta (β^-) radiation?

a. ^{1}H
b. ^{2}H
c. ^{3}H
d. ^{14}N
e. ^{55}Mn