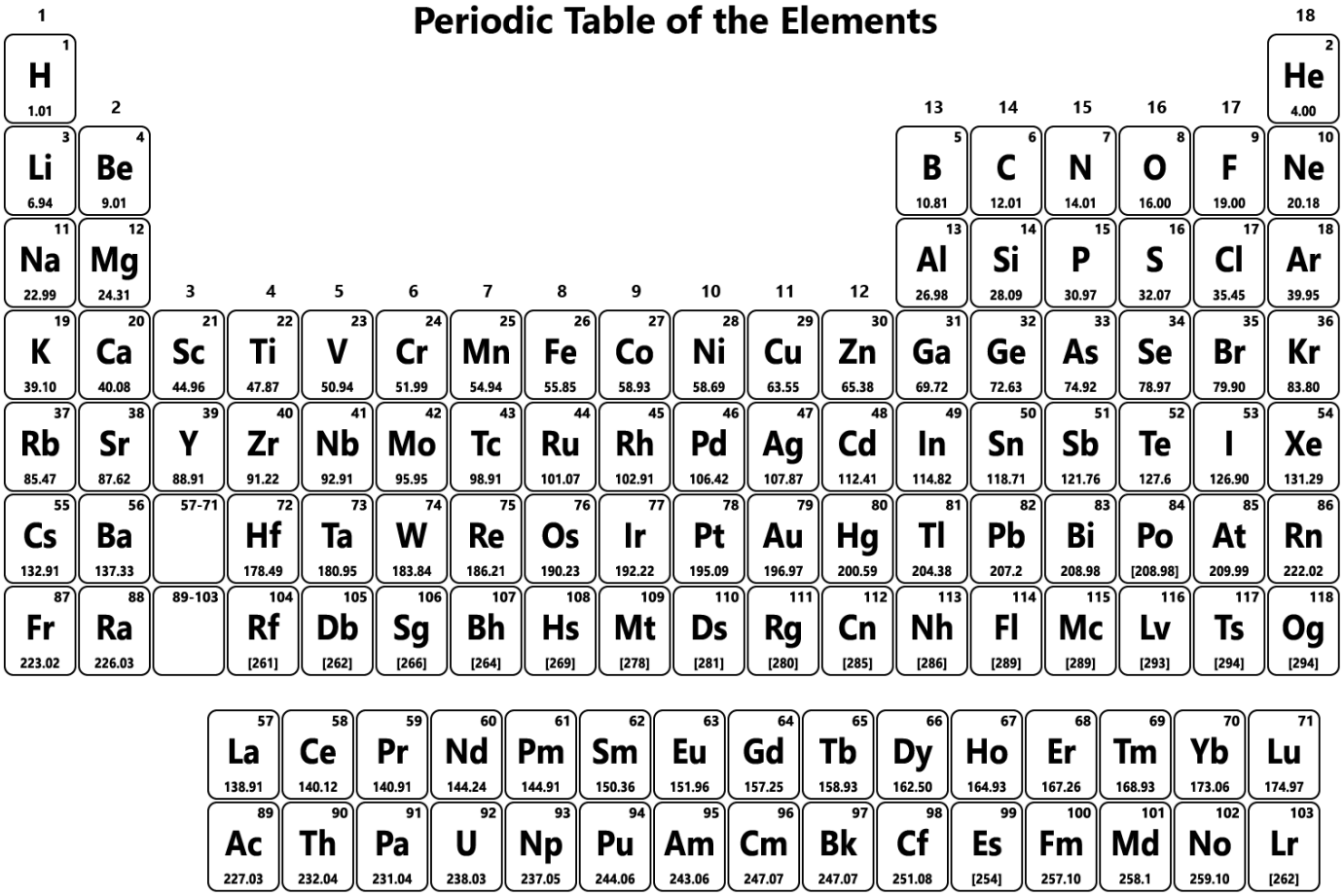
Section II: Chemistry

Suggested Time: 20 minutes
30 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)



Questions:

1. A student was given an aqueous solution of zinc chloride, in which the presence of 1.806×10^{22} chloride ions and 11.56 g of undissociated zinc chloride salt was determined. The degree of dissociation of this salt in this solution is:
   a) 35.3 %;
   b) 30.0 %;
   c) 17.6 %;
   d) 15.0 %;
   e) 13.2 %.

2. The oxygen atoms in the O_3 molecule possess the following type of hybridization:
   a) sp;
   b) sp^2;
   c) sp^3;
   d) sp^3d;
   e) not all the oxygen atoms have the same hybridization state.

3. 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 an unbalanced half-reaction of an oxidation process?
   a) $MnO_4^{22} + H^+ \rightarrow Mn^{2+} + H_2O$;
   b) $Ag[(NH_3)_2] \rightarrow Ag + NH_3$;
   c) $S_2O_8^{2-} \rightarrow SO_4^{2-}$;
   d) $BiO_3^- + H^+ \rightarrow Bi^{3+} + H_2O$;
   e) $S_2O_3^{2-} \rightarrow S_4O_6^{2-}$.

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

5. A student observes that three identical containers, filled with oxygen (a), with nitrogen (b), and with carbon dioxide (c), have the same mass under standard conditions. The arrangement of the containers in order of increasing volume that the gases will occupy is given by the following ordering:
   a) $a < b < c$;
   b) $c < a < b$;
   c) $b < a < c$;
   d) $c < b < a$,
   e) $a < c < b$.

6. 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^-.

7. Magnesium naturally occurs in the following three stable isotopes: ^{24}Mg, ^{25}Mg, and ^{26}Mg. Knowing that the abundance of the ^{25}Mg isotope in nature is 10%, the abundance of the ^{24}Mg isotope is given by:
   a) 79.75%;
   b) 10.125%;
   c) 89.875%;
   d) 20.25%;
   e) 45.0% .

8. A student wrote the following reaction on the board, which you decided to balance in your school break as a fellow chemistry enthusiast: $S_8(s) + NaOH\ (aq) \rightarrow Na_2S_2O_3(aq) + Na_2S\ (aq) + H_2O\ (l)$. What is the sum of the coefficients you got?
   a) 12;
   b) 24;
   c) 16;
   d) 25;
   e) 13.

9. Which of the following compounds doesn't have a total of 24 electrons in the valence layers of the elements it is made up from?
   a) SO_3;
   b) H_3PO_3;
   c) $AlCl_3$;
   d) HNO_3;
   e) Al_2O_3.

10. Which of the following molecules exhibits a different electron-pair geometry from the others?
    a) BH_3;
    b) H_2O;
    c) SO_4^{2-};
    d) CH_4;
    e) PO_4^{3-}; .

11. Given that all gasses are at STP (1 atm, 273.15K), the volume of ozonized oxygen in which the mole fraction of ozone is 24%, required for the combustion of 22.4 L of hydrogen, is approximately equal to: (Note: Assume O_3 can completely combust H_2).
    a) 5 L;
    b) 10 L;
    c) 11.2 L;
    d) 22.4 L;
    e) 44.8 L.

12. Upon adding excess concentrated sulfuric acid to 34.8 g of solid fluoride of an unknown alkali metal, a student observed the release of a gas, which formed 23.4 g of an unknown precipitate when passed through a solution of $Ca(OH)_2$. Knowing all of the above, the student found the unknown alkali metal is:
    a) Li;
    b) Na;
    c) K;
    d) Rb;
    e) Cs.

13. A student decided to monitor the concentration of reactant **X** at different times during the reaction. Determine the order of reactant **X** in the rate-law given the summarized results registered by in the table.

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

    a) 0th order;
    b) 1st order;
    c) 2th order;
    d) 3rd order;
    e) there is not enough information to determine the order.

14. A student wrote the following reaction on the board, which you decided to balance in your school break: $Na_2S_2O_3$ (aq) + I_2 (s) + NaOH (aq) → NaI (aq) + Na_2SO_4 (aq) + H_2O (l). What is the sum of the **left hand-side** coefficients you got?
    a) 29;
    b) 15;
    c) 6;
    d) 30;
    e) 14.

15. Which of the following anions does not participate in the electrolysis at the anode?
    a) CH_3COO^-;
    b) HO^-;
    c) S^{2-};
    d) SO_3^{2-};
    e) Br^-.

16. Upon combustion of a gaseous mixture containing methane given by the formula CH_4 and ethane given by the formula C_2H_6 in excess of oxygen, 2.688 L of carbon dioxide (at STP, 1 atm and 273.15K) and 3.78 g of water were produced. What is the volume ratio of methane to ethane in the initial mixture?
    a) 1:1;
    b) 1:2;
    c) 2:1;
    d) 1:4;
    e) 4:1.

17. A student tries to dissolve 185g of $MnCl_2$ in 220g of H_2O at 20 °C, forgetting to check that the solubility of $MnCl_2$ is 74g/100 ml at 20 °C before starting. The resulting solution will be:
    a) Saturated;
    b) Unsaturated;
    c) Supersaturated;
    d) it depends on whether the student dissolves the salt all at once or gradually;
    e) it depends on whether the student stirs the solution at the end or continuously.

18. A student was given an unknown gaseous compound containing only sulfur and fluorine, which at 300 K and 100 kPa occupies a volume of 2.4942 L and weighs a mass of 2.55g. The formula of the unknown compound is given by:
    (Note: 1 atm = 101.3 kPa)
    a) SF_2;
    b) SF_4;
    c) SF_6;
    d) S_2F_2;
    e) S_2F_{10}.

19. Which of the following options represents the correct arrangement of ions in increasing order of ionic radius?
    a) $Se^{-2} < S^{-2} < Cl^- < K^+ < Mg^{+2} < Ca^{+2}$;
    b) $Mg^{+2} < Ca^{+2} < K^+ < S^{-2} < Se^{-2} < Cl^-$;
    c) $K^+ < Mg^{+2} < Ca^{+2} < Cl^- < S^{-2} < Se^{-2}$;
    d) $Cl^- < Se^{-2} < S^{-2} < K^+ < Ca^{+2} < Mg^{+2}$;
    e) $Mg^{+2} < Ca^{+2} < K^+ < Cl^- < S^{-2} < Se^{-2}$.

20. In the atmosphere, molecular oxygen reacts with an oxygen atom to produce ozone via the reaction $O_2+O \cdot \rightarrow O_3$, and at the same time ozone reacts with an oxygen atom to form molecular oxygen via the reaction $O_3+O \cdot \rightarrow O_2$, which are the main steps of the ozone layer formation process. The reactions above are called:
    a) polymerization reactions;
    b) hydrolysis reactions;
    c) neutralization reactions;
    d) combustion reactions;
    e) radical reactions.

21. A student adds 1 mol of each of different compounds to water, then measures the pH using pH paper strips. The lowest pH will be given by the following compound:
    a) NH_3;
    b) NaBr;
    c) HNO_3;
    d) HF;
    e) $FeCl_3$.

22. Both solubility and solubility product constant denoted as K_{sp} are important when describing compounds. A student knows that the solubility product constant of $Ca_3(PO_4)_2$ is given by $K_{sp} = 1.0* 10^{-25}$. Then, the solubility of $Ca_3(PO_4)_2$ must be given by:
    a) $3.920* 10^{-6}$ mol/L;
    b) $1.0* 10^{-5}$ mol/L;
    c) $1.215* 10^{-3}$ mol/L;
    d) $3.1* 10^{-3}$ mol/L.
    e) there is not enough information to find out.

23. The element with the lowest ionization energy out of the following is:
    a) Beryllium
    b) Boron;
    c) Caron;
    e) Oxygen;
    d) Nitrogen.

24. 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. You can deduce that the mystery metal is:
    a) Nickel;
    b) Zinc;
    c) Copper;
    e) Iron;
    d) Manganese.

25. An aqueous perchloric acid solution contains 18 times more oxygen atoms than chlorine atoms. The mass fraction of perchloric acid in this aqueous solution is:
    a) 58.26%;
    b) 28.51%;
    c) 23.67%;
    e) 24.72%;
    d) 84.81%.

26. When concentrated HNO_3 reacts with aluminum metal, which of the following forms?
    a) NH_4NO_3;
    b) N_2O;
    c) NO;
    d) NO_2;
    e) Aluminium metal doesn't react with concentrated HNO_3.

27. The central atom in the SF_6 molecule possesses the following type of hybridization:
    a) sp;
    b) sp^2;
    c) sp^3;
    d) sp^3d;
    e) sp^3d^2.

28. Some students want to find the number of water molecules in a sample of the hydrated magnesium sulfate. They observed that 4.92 g of hydrated magnesium sulfate reacted with 50 ml of 0.5 M NaOH solution until the salt decomposed completely. Then, they reacted the excess from the 0.5 M of NaOH solution with 5 ml of 2 M H_2SO_4 solution until the neutralization of the solution was complete. The number of water molecules in the hydrated magnesium sulfate is:
    a) 3;
    b) 5;
    c) 7;
    d) 10;
    e) 14.

29. Which of the following compounds can act as both a reducing and an oxidizing agent?
    a) Cl_2;
    b) $KMnO_4$;
    c) NH_3;
    d) K_2FeO_4
    e) FeO.

30. What is the pH of a 500.0 mL solution of 2.00 M acetic acid when mixed with 50.0 mL of 1.50 M sodium hydroxide if the pKa of acetic acid is 4.76?
    a) 3.67;
    b) 4.76;
    c) 7.23;
    d) 9.67;
    e) 14.18.