CHAPTER 5 QUESTIONS

Multiple-Choice Questions

Use the following solubility rules to answer questions 1-4.

Salts containing halide anions are soluble except for those containing Ag^+, Pb^{2+}, and Hg_2^{2+}.

Salts containing carbonate anions are insoluble except for those containing alkali metals or ammonium.

1. If solutions of iron (III) nitrate and sodium carbonate are mixed, what would be the formula of the precipitate?

   (A) Fe_3CO_3
   (B) $Fe_2(CO_3)_3$
   (C) $NaNO_3$
   (D) No precipitate would form.

2. If solutions containing equal amounts of $AgNO_3$ and KCl are mixed, what is the identity of the spectator ions?

   (A) Ag^+, NO_3^-, K^+, and Cl^-
   (B) Ag^+ and Cl^-
   (C) K^+ and Ag^+
   (D) K^+ and NO_3^-

3. If equimolar solutions of $Pb(NO_3)_2$ and NaCl are mixed, which ion will not be present in significant amounts in the resulting solution after equilibrium is established?

   (A) Pb^{2+}
   (B) NO_3^-
   (C) Na^+
   (D) Cl^-

4. Choose the correct net ionic equation representing the reaction that occurs when solutions of potassium carbonate and copper (I) chloride are mixed.

   (A) $K_2CO_3(aq) + 2CuCl(aq) \rightarrow 2KCl(aq) + Cu_2CO_3(s)$
   (B) $K_2CO_3(aq) + 2CuCl(aq) \rightarrow 2KCl(s) + Cu_2CO_3(aq)$
   (C) $CO_3^{2-} + 2Cu^+ \rightarrow Cu_2CO_3(s)$
   (D) $CO_3^{2-} + Cu^{2+} \rightarrow CuCO_3(s)$

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5. A strip of metal X is placed into a solution containing Y^{2+} ions and no reaction occurs. When metal X is placed in a separate solution containing Z^{2+} ions, metal Z starts to form on the strip. Which of the following choices organizes the reduction potentials for metals X, Y, and Z from greatest to least?

   (A) X > Y > Z
   (B) Y > Z > X
   (C) Z > X > Y
   (D) Y > X > Z

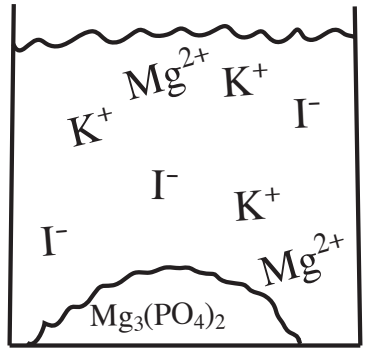
6. Which of the following is true for an endothermic reaction?
   (A) The strength of the bonds in the products exceeds the strength of the bonds in the reactants.
   (B) The activation energy is always greater than the activation energy for an exothermic reaction.
   (C) Energy is released over the course of the reaction.
   (D) A catalyst will increase the rate of the reaction by increasing the activation energy.

7. In which of the following compounds is the oxidation number of chromium the greatest?
   (A) CrO_4^{2-}
   (B) CrO
   (C) Cr^{3+}
   (D) $Cr(s)$

8. For an endothermic reaction, which of the following is true regarding the energy level of the activated complex?
   (A) It is above the energy level of the reactants, but below the energy level of the products.
   (B) It is below the energy level of the reactants, but above energy level of the products.
   (C) It is above the energy level of both the products and reactants.
   (D) It is below the energy level of both the products and reactants.

9. Based on the particulate drawing of the products for the reaction below, which reactant is limiting for the following reaction and why?

$$2K_3PO_4(aq) + 3MgI_2(aq) \rightarrow Mg_3(PO_4)_2(s) + 6KI(aq)$$



   (A) The K_3PO_4, because there are no excess PO_4^{3-} ions after the reaction
   (B) The MgI_2, because there are excess Mg^{2+} cations remaining after the reaction
   (C) The K_3PO_4, because it contains a cation that cannot form a precipitate
   (D) The MgI_2, because it requires more of itself to create the products

10. What is the mass of oxygen in 148 grams of calcium hydroxide ($Ca(OH)_2$)?
   (A) 24 grams
   (B) 32 grams
   (C) 48 grams
   (D) 64 grams

11. A sample of a compound known to consist of only carbon, hydrogen, and oxygen is found to have a total mass of 29.05 g. If the mass of the carbon is 18.02 g and the mass of the hydrogen is 3.03 g, what is the empirical formula of the compound?

(A) C_2H_4O
(B) C_3H_6O
(C) $C_2H_6O_3$
(D) $C_3H_8O_2$

Use the following information to answer questions 12-15.

When heated in a closed container in the presence of a catalyst, potassium chlorate decomposes into potassium chloride and oxygen gas via the following reaction:

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

12. If 12.25 g of potassium chlorate decomposes, how many grams of oxygen gas will be generated?

(A) 1.60 g
(B) 3.20 g
(C) 4.80 g
(D) 18.37 g

13. Approximately how many liters of oxygen gas will be evolved at STP?

(A) 2.24 L
(B) 3.36 L
(C) 4.48 L
(D) 22.4 L

14. If the temperature of the gas is doubled while the volume is held constant, what will happen to the pressure exerted by the gas and why?

(A) It will also double, because the gas molecules will be moving faster.
(B) It will also double, because the gas molecules are exerting a greater force on each other.
(C) It will be cut in half, because the molecules will lose more energy when colliding.
(D) It will increase by a factor of 4, because the kinetic energy will be four times greater.

15. Why is a catalyst present during the reaction?

(A) A catalyst is necessary for all decomposition reactions to occur.
(B) A catalyst reduces the bond energy in the reactants, making them easier to activate.
(C) A catalyst reduces the energy differential between the reactants and the products.
(D) A catalyst lowers the activation energy of the overall reaction and speeds it up.

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16. A sample of a hydrate of $CuSO_4$ with a mass of 250 grams was heated until all the water was removed. The sample was then weighed and found to have a mass of 160 grams. What is the formula for the hydrate?

(A) $CuSO_4 \cdot 10H_2O$
(B) $CuSO_4 \cdot 7H_2O$
(C) $CuSO_4 \cdot 5H_2O$
(D) $CuSO_4 \cdot 2H_2O$

17. $$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$$

If the reaction above took place at standard temperature and pressure and 150 grams of $CaCO_3(s)$ were consumed, what was the volume of $CO_2(g)$ produced at STP?

(A) 11 L
(B) 22 L
(C) 34 L
(D) 45 L

18. A gaseous mixture at 25°C contained 1 mole of CH_4 and 2 moles of O_2 and the pressure was measured at 2 atm. The gases then underwent the reaction shown below.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

What was the pressure in the container after the reaction had gone to completion and the temperature was allowed to return to 25°C?

(A) 1 atm
(B) 2 atm
(C) 3 atm
(D) 4 atm

19. During a chemical reaction, $NO(g)$ gets reduced and no nitrogen-containing compound is oxidized. Which of the following is a possible product of this reaction?

(A) $NO_2(g)$
(B) $N_2(g)$
(C) $NO_3^-(aq)$
(D) $NO_2^-(aq)$

20. $$Cr_2O_7^{2-} + 6I^- + 14H^+ \rightarrow 2Cr^{3+} + 3I_2 + 7H_2O$$

Which of the following statements about the reaction given above is NOT true?

(A) The oxidation number of chromium changes from +6 to +3.
(B) The oxidation number of iodine changes from –1 to 0.
(C) The oxidation number of hydrogen changes from +1 to 0.
(D) The oxidation number of oxygen remains the same.

21. Which expression below should be used to calculate the mass of copper that can be plated out of a 1.0 *M* $Cu(NO_3)_2$ solution using a current of 0.75 A for 5.0 minutes?

(A) $\dfrac{(5.0)(60)(0.75)(63.55)}{(96500)(2)}$

(B) $\dfrac{(5.0)(60)(63.55)(2)}{(0.75)(96500)}$

(C) $\dfrac{(5.0)(60)(96500)(0.75)}{(63.55)(2)}$

(D) $\dfrac{(5.0)(60)(96500)(63.55)}{(0.75)(2)}$

22. $Cu^{2+} + 2e^- \rightarrow Cu$ $\quad E° = +0.3$ V
$Fe^{2+} + 2e^- \rightarrow Fe$ $\quad E° = -0.4$ V

Based on the reduction potentials given above, what is the reaction potential for the following reaction?

$$Fe^{2+} + Cu \rightarrow Fe + Cu^{2+}$$

(A) –0.7 V
(B) –0.1 V
(C) +0.1 V
(D) +0.7 V

23. $Cu^{2+} + 2e^- \rightarrow Cu$ $\quad E° = +0.3$ V
$Zn^{2+} + 2e^- \rightarrow Zn$ $\quad E° = -0.8$ V
$Mn^{2+} + 2e^- \rightarrow Mn$ $\quad E° = -1.2$ V

Based on the reduction potentials given above, which of the following reactions will be favored?

(A) $Mn^{2+} + Cu \rightarrow Mn + Cu^{2+}$
(B) $Mn^{2+} + Zn \rightarrow Mn + Zn^{2+}$
(C) $Zn^{2+} + Cu \rightarrow Zn + Cu^{2+}$
(D) $Zn^{2+} + Mn \rightarrow Zn + Mn^{2+}$

24. Molten $AlCl_3$ is electrolyzed with a constant current of 5.00 amperes over a period of 600.0 seconds. Which of the following expressions is equal to the maximum mass of Al(*s*) that plates out? (1 faraday = 96,500 coulombs)

(A) $\dfrac{(600)(5.00)}{(96{,}500)(3)(27.0)}$ grams

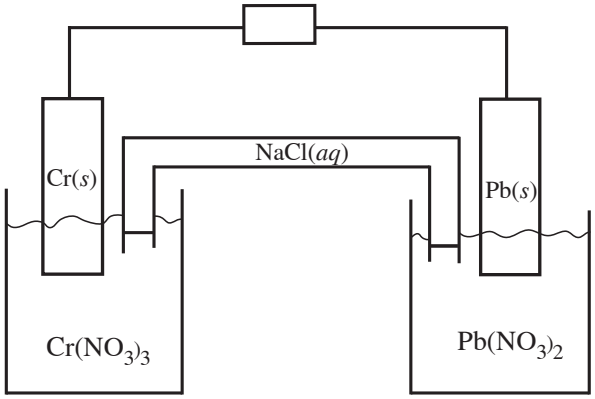
(B) $\dfrac{(600)(5.00)(3)(27.0)}{(96{,}500)}$ grams

(C) $\dfrac{(600)(5.00)(27.0)}{(96{,}500)(3)}$ grams

(D) $\dfrac{(96{,}500)(3)(27.0)}{(600)(5.00)}$ grams

Use the following information to answer questions 25-28.

A voltaic cell is created using the following half-cells:



$Cr^{3+} + 3e^- \rightarrow Cr(s)$ $\quad E° = -0.41$ V
$Pb^{2+} + 2e^- \rightarrow Pb(s)$ $\quad E° = -0.12$ V

The concentrations of the solutions in each half-cell are 1.0 *M*.

25. Which of the following occurs at the cathode?

(A) Cr^{3+} is reduced to $Cr(s)$.
(B) Pb^{2+} is reduced to $Pb(s)$.
(C) $Cr(s)$ is oxidized to Cr^{3+}.
(D) $Pb(s)$ is oxidized to Pb^{2+}.

26. Which net ionic equation below represents a possible reaction that takes place when a strip of magnesium metal is oxidized by a solution of chromium (III) nitrate?

(A) $Mg(s) + Cr(NO_3)_3(aq) \rightarrow Mg^{2+}(aq) + Cr^{3+}(aq) + 3NO_3^-(aq)$
(B) $3Mg(s) + 2Cr^{3+} \rightarrow 3Mg^{2+} + 2Cr(s)$
(C) $Mg(s) + Cr^{3+} \rightarrow Mg^{2+} + Cr(s)$
(D) $3Mg(s) + 2Cr(NO_3)_3(aq) \rightarrow 3Mg^{2+}(aq) + 2Cr(s) + NO_3^-(aq)$

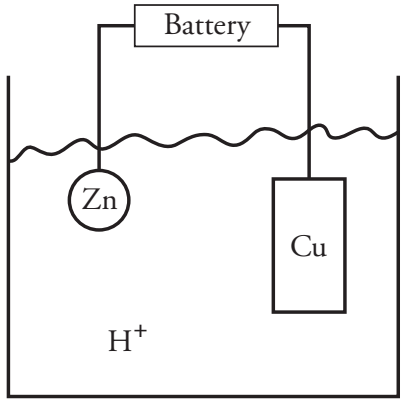
27. Which of the following best describes the activity in the salt bridge as the reaction progresses?

(A) Electrons flow through the salt bridge from the Pb/Pb^{2+} half-cell to the Cr/Cr^{3+} half-cell.
(B) Pb^{2+} flows to the Cr/Cr^{3+} half-cell, and Cr^{3+} flows to the Pb/Pb^{2+} half-cell.
(C) Na^+ flows to the Cr/Cr^{3+} half-cell, and Cl^- flows to the Pb/Pb^{2+} half-cell.
(D) Na^+ flows to the Pb/Pb^{2+} half-cell, and Cl^- flows to the Cr/Cr^{3+} half-cell.

28. Based on the given reduction potentials, which of the following would lead to a reaction?

(A) Placing some $Cr(s)$ in a solution containing Pb^{2+} ions
(B) Placing some $Pb(s)$ in a solution containing Cr^{3+} ions
(C) Placing some $Cr(s)$ in a solution containing Cr^{3+} ions
(D) Placing some $Pb(s)$ in a solution containing Pb^{2+} ions

Use the following information to answer questions 29-31.



Pennies are made primarily of zinc, which is coated with a thin layer of copper through electroplating, using a setup like the one above. The solution in the beaker is a strong acid (which produces H^+ ions), and the cell is wired so that the copper electrode is the anode and zinc penny is the cathode. Use the following reduction potentials to answer questions 29-31.

Half-Reaction	Standard Reduction Potential
$Cu^{2+} + 2e^- \rightarrow Cu(s)$	+0.34 V
$2H^+ + 2e^- \rightarrow H_2(g)$	0.00 V
$Ni^{2+} + 2e^- \rightarrow Ni(s)$	–0.25 V
$Zn^{2+} + 2e^- \rightarrow Zn(s)$	–0.76 V

29. When the cell is connected, which of the following reactions takes place at the anode?

(A) $Cu^{2+} + 2e^- \rightarrow Cu(s)$
(B) $Cu(s) \rightarrow Cu^{2+} + 2e^-$
(C) $2H^+ + 2e^- \rightarrow H_2(g)$
(D) $H_2(g) \rightarrow 2H^+ + 2e^-$

30. What is the required voltage to make this cell function?

(A) 0.34 V
(B) 0.42 V
(C) 0.76 V
(D) 1.10 V

31. If, instead of copper, a nickel bar were to be used, could nickel be plated onto the zinc penny effectively? Why or why not?

(A) Yes, nickel's SRP is greater than that of zinc, which is all that is required for nickel to be reduced at the cathode
(B) Yes, nickel is able to take electrons from the H^+ ions in solution, allowing it to be reduced
(C) No, nickel's SRP is lower than that of H^+ ions, which means the only product being produced at the cathode would be hydrogen gas
(D) No, nickel's SRP is negative, meaning it cannot be reduced in an electrolytic cell

Free-Response Questions

1. 2.54 g of beryllium chloride are completely dissolved into 50.00 mL of water inside a beaker.
   (a) Draw a particulate representation of all species in the beaker after the solute has dissolved. Your diagram should include at least one beryllium ion, one chloride ion, and four water molecules. Make sure the atoms and ions are correctly sized and oriented relative to each other.
   (b) What is the concentration of beryllium and chloride ions in the beaker?

   A solution of 0.850 *M* lead nitrate is then titrated into the beaker, causing a precipitate of lead (II) chloride to form.

   (c) Identify the net ionic reaction occurring in the beaker.
   (d) What volume of lead nitrate must be added to the beaker to cause the maximum precipitate formation?
   (e) What is the theoretical yield of precipitate?
   (f) Students performing this experiment suggested the following techniques to separate the precipitate from the water. Their teacher rejected each idea. Explain why the teacher may have done so, and name the inherent errors of
      (i) boiling off the water
      (ii) decanting (pouring off) the water

2. Hydrogen peroxide, H_2O_2, is a common disinfectant. Pure hydrogen peroxide is a very strong oxidizer, and as such, it is diluted with water to low percentages before being bottled and sold. One method to determine the exact concentration of H_2O_2 in a bottle of hydrogen peroxide is to titrate a sample with a solution of acidified potassium permanganate. This causes the following redox reactions to occur:

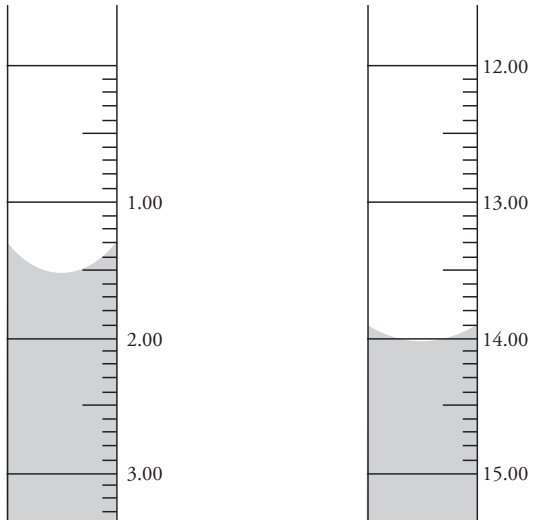
   Reduction: $8H^+ + MnO_4^- + 5e^- \rightarrow Mn^{2+} + 4H_2O(l)$

   Oxidation: $H_2O_2(aq) \rightarrow 2H^+ + O_2(g) + 2e^-$

   During a titration, a student measures out 5.0 mL of hydrogen peroxide solution into a graduated cylinder, and he pours it into a flask, diluting it to 50.0 mL with water. The student then titrates 0.150 *M* potassium permanganate solution into the flask with constant stirring.

   (a) Write out the full, balanced redox reaction that is taking place during the titration.
   (b) List two observations that the student will see as the titration progresses that are indicative of chemical reactions.

Diagrams of the permanganate in the buret at the start and end of the titration are as follows:



(c) (i) What volume of $KMnO_4$ was titrated?
(ii) What is the concentration of hydrogen peroxide in the original sample?

(d) How would the precision of the student's results have changed if the hydrogen peroxide sample were measured out in a 50 mL beaker instead of a graduated cylinder?

(e) How would each of the following errors affect the student's final calculated hydrogen peroxide concentration?
(i) Not filling the buret tip with solution prior to the titration
(ii) Not rinsing down the sides of the flask during titration

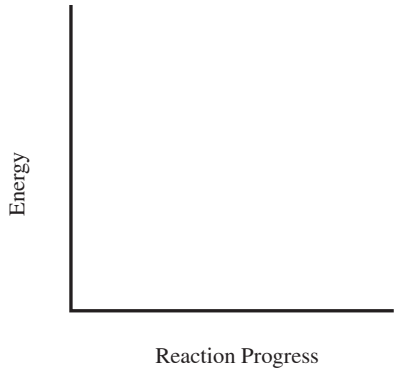
3. Acetylene (C_2H_2) is a fuel that is commonly used in metallurgical applications, particularly welding.

(a) Draw the Lewis diagram for acetylene.

(b) Write out and balance the reaction that occurs when acetylene is combusted in the atmosphere.

The combustion of acetylene is a very exothermic process.

(c) On the empty reaction coordinates below, draw an energy diagram for ethylene, labeling both the energy level for both the reactants and the products, as well as labeling the ΔH value for the reaction.



(d) For this reaction, are the bonds more stable in the reactants or in the products? Why?

4. $2Mg(s) + 2CuSO_4(aq) + H_2O(l) \rightarrow 2MgSO_4(aq) + Cu_2O(s) + H_2(g)$

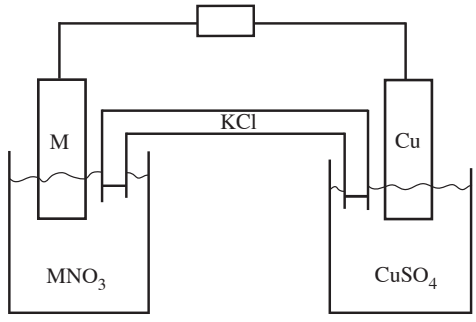
(a) If 1.46 grams of Mg(*s*) are added to 500 milliliters of a 0.200-molar solution of $CuSO_4$, what is the maximum molar yield of $H_2(g)$?

(b) When all of the limiting reagent has been consumed in (a), how many moles of the other reactant (not water) remain?

(c) What is the mass of the Cu_2O produced in (a)?

(d) What is the value of $[Mg^{2+}]$ in the solution at the end of the experiment? (Assume that the volume of the solution remains unchanged.)

5. A student performs an experiment in which a bar of unknown metal M is placed in a solution with the formula MNO_3. The metal is then hooked up to a copper bar in a solution of $CuSO_4$ as shown below. A salt bridge that contains aqueous KCl links the cell together.



The cell potential is found to be +0.74 V. Separately, when a bar of metal M is placed in the copper sulfate solution, solid copper starts to form on the bar. When a bar of copper is placed in the MNO_3 solution, no visible reaction occurs.

The following gives some reduction potentials for copper:

Half-reaction	$E°$
$Cu^{2+} + 2e^- \rightarrow Cu(s)$	0.34 V
$Cu^{2+} + e^- \rightarrow Cu^+$	0.15 V
$Cu^+ + e^- \rightarrow Cu(s)$	0.52 V

(a) Write the net ionic equation that takes place in the Cu/M cell.
(b) What is the standard reduction potential for metal M?
(c) Which metal acted as the anode and which as the cathode? Justify your answer.
(d) On the diagram of the cell, indicate which way the electrons are flowing in the wire. Additionally, indicate any ionic movement occurring in the salt bridge.
(e) What would happen to the voltage of the reaction in the Cu/M cell if the concentration of the $CuSO_4$ increased while the concentration of the MNO_3 remained constant? Justify your answer.

6. Two electrodes are inserted into a solution of nickel (II) fluoride and a current of 2.20 A is run through them. A list of standard reduction potentials is as follows:

Half-reaction	$E°$
$O_2(g) + 4H^+ + 4e^- \rightarrow H_2O(l)$	1.23 V
$F_2(g) + 2e^- \rightarrow 2F^-$	2.87 V
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-$	–0.83 V
$Ni^{2+} + 2e^- \rightarrow Ni(s)$	–0.25 V

(a) Write the net ionic equation that takes place during this reaction.
(b) Qualitatively describe what an observer would see taking place at each electrode.
(c) Will the solution become acidic, basic, or remain neutral as the reaction progresses?
(d) How long would it take to create 1.2 g of Ni(*s*) at the cathode?