SOLUTIONS

CHEMISTRY PRACTICE PROBLEMS FOR NON-TECHNICAL MAJORS

Section 1:

1.1 Define mole, Avogadro's number, GAW, and GFW. In 500 grams of Na_3PO_4 , how many grams and moles of each constituent element are there?

Mole: 6.02 x 10^{23} atoms (or molecules, etc.)
Avogadro's number: 6.02 x 10^{23} atoms in X grams of any element, where X is the atomic weight of the element
GAW: Gram Atomic Weight, the mass of one mole of atoms
GFW: Gram Formula Weight, the mass of one mole of molecules

The GFW of Na_3PO_4 is: (3x22.99 + 30.97 + 4x15.999)g = 163.94 grams

500 g Na_3PO_4	**1 mole**	$\boxed{= 3.05 \text{ moles } Na_3PO_4}$
	163.94 g	

For each mole of Na_3PO_4 , there are 3 moles of sodium (Na atoms), 1 mole of phosphorus (P atoms), and 4 moles of oxygen (O atoms) according to the chemical formula.
Therefore:

3.05 moles Na_3PO_4	**3 moles Na**	$\boxed{= 9.15 \text{ moles Na}}$
	1 mole Na_3PO_4	

9.15 moles Na	**22.99 g Na**	$\boxed{= 210.4 \text{ grams Na}}$
	1 mole Na	

3.05 moles Na_3PO_4	**1 mole P**	$\boxed{= 3.05 \text{ moles P}}$
	1 mole Na_3PO_4	

3.05 moles P	**30.97 g P**	$\boxed{= 94.5 \text{ grams P}}$
	1 mole P	

3.05 moles Na_3PO_4	**4 moles O**	$\boxed{= 12.20 \text{ moles O}}$
	1 mole Na_3PO_4	

12.20 moles O	**15.999 g O**	$\boxed{= 195.2 \text{ grams O}}$
	1 mole O	

Double-check the math by adding the results found for masses of the three constituent elements in Na_3PO_4: 210.4 g + 94.5 g + 195.2 g = 500.1 grams (within roundoff of 500 g)

1.2 State the three classes of elements. Give several examples for each. What is a period on the periodic table? What is a group on the periodic table? What do each of these classifications indicate about the elements within them?

Metals: Na, Mg, Sn, Mn, Co, among others
Non-Metals: C, N, Br, Kr, among others
Semi-Metals: B, Si, Ge, As, Sb, Te, Po, At

Period: horizontal row on the Periodic Table, indicates the number of electron shells
Group: vertical column on the Periodic Table, indicates the number of electrons in the outer shell (and thus similar chemical properties)

1.3 Given one neutral atom of magnesium, state the following:

# of protons **12**
# of electrons **12**
# of neutrons **12**
atomic weight **24.312 amu**
class of element **metal**
period **3rd**
group **IIA**
other elements with similar properties **Be, Ca, Sr, Ba, Ra**

1.4 Given that every atom of neutral calcium has two electrons in its outer shell, how many electrons does magnesium have in its outer shell? Why?
2, because Mg is in the same group as Ca.

Section 2:

2.1 Describe the differences between ionic bonds and covalent bonds.

- **An ionic bond is formed when one or more electrons is WHOLLY TRANSFERRED from one element to another, resulting in ions with opposite charges attracting each other.**

- **A covalent bond is formed when one or more electrons from one atom pair off with electrons of another atom to form overlapping electron shells. Both atoms SHARE the paired electrons with a covalent bond. The atoms involved remain neutral; no ions are involved.**

- **The FORCE OF ATTRACTION due to the opposing charges is what holds the elements together with an ionic bond. The ENERGY DIFFERENCE is what holds the elements together with a covalent bond.**

- **The ionic bond holds many atoms together rather than a bond between individual atoms. A covalent bond holds together specific atoms.**

2.2 Describe the difference between covalent bonds and Van der Waals forces.

- **Covalent bonds exist between the atoms WITHIN a molecule. Van der Waals forces occur BETWEEN the molecules of nonpolar covalent substances.**

2.3 Explain the difference between solubility, solution, solvent, and solute.

- **A solvent is the material that dissolves the other substance(s). A solute is the substance that is dissolved in the solution.**
- **A solution is a homogeneous mixture of two or more substances and consists of a solvent and one or more solutes.**
- **Solubility is the maximum amount of substance (solute) that can dissolve in a given solvent at a specific temperature.**

2.4 Calculate the molarity of the resulting solution if 20 grams of HCl are placed in sufficient water to make exactly 5 liters of final solution.

$$\textbf{Molarity is } \frac{\textbf{moles of solute}}{\textbf{liters of solution}}$$

$$\begin{array}{c|c} \textbf{20 g HCl} & \textbf{1 mole HCl} \\ \hline & \textbf{(1 + 35.5) g HCl} \end{array} = 0.548 \text{ mole HCl}$$

$$\frac{\textbf{0.548 mole HCl}}{\textbf{5 L soln}} = \boxed{0.1096 \text{ M}}$$

2.5 Prepare a 0.4 M solution of HCl.

$$\textbf{0.4 M} = \frac{\textbf{X moles HCl}}{\textbf{1 L Soln}} \qquad \textbf{X = 0.4 moles HCl}$$

$$\textbf{0.4 moles} = \frac{\textbf{Y grams HCl}}{\textbf{36.5 g HCl}} \qquad \boxed{\textbf{Y= 14.6 g HCl}}$$

14.6 grams of HCl is weighed out and sufficient water is added to bring the amount of final solution to 1 liter. Note that the volume of water added will be LESS than 1 liter.

2.6 Balance the following reaction equation:

$\underline{\textbf{1}}CS_2 + \underline{\textbf{3}}O_2 \rightarrow \underline{\textbf{1}}CO_2 + \underline{\textbf{2}}SO_2$

2.7 How many grams of SO_2 would be produced in the preceding reaction from 200 g of CS_2 assuming a sufficient amount of O_2 is available?

$$\frac{\mathbf{200\text{ g }CS_2}}{\mathbf{76.139\text{ GFW }CS_2}} = \mathbf{2.6268\text{ moles }CS_2}$$

$$\begin{array}{l|c|c} \mathbf{2.6268\text{ moles }CS_2} & \mathbf{2\text{ moles }SO_2} & \mathbf{64.062\text{ g GFW }SO_2} \\ \hline & \mathbf{1\text{ mole }CS_2} & \mathbf{1\text{ mole }SO_2} \end{array} \quad \boxed{= \mathbf{336.56\text{ g }SO_2}}$$

2.8 Balance the following reaction equation:

$\underline{2}Cr_2O_3 + \underline{3}O_2 + \underline{4}H_2O \rightarrow \underline{4}H_2CrO_4$

2.9 If 50 grams of H_2CrO_4 were produced when the preceding reaction took place in 0.5 liters of water, what was the molarity of the original Cr_2O_3?

$$\begin{array}{l|c|c} \mathbf{50\text{ g }H_2CrO_4} & \mathbf{1\text{ mole }H_2CrO_4} & \mathbf{2\text{ moles }Cr_2O_3} \\ \hline & \mathbf{118.008\text{ g }H_2CrO_4} & \mathbf{4\text{ moles }H_2CrO_4} \end{array} \quad = \mathbf{0.212\text{ mole }Cr_2O_3}$$

$$\frac{\mathbf{0.212\text{ mole }Cr_2O_3}}{\mathbf{0.5\text{ liter }H_2O}} \quad \boxed{= \mathbf{0.424\ \underline{M}\ Cr_2O_3}}$$

Section 3:

3.1 State the problems associated with uncontrolled corrosion in a reactor plant.

- **Corrosion could lead to penetration of the metal containing the coolant and result in a leak that could jeopardize safe operation.**
- **Corrosion of the cladding could cause it to become more brittle and blister, resulting in radioactive fission product release to the coolant.**
- **Corrosion products may be deposited on core surfaces resulting in fouling of heat transfer surfaces and accelerated wear of moving parts by corrosion products trapped between them.**
- **Corrosion products can become radioactive and re-deposit themselves outside of the core resulting in elevated radiation levels after shutdown, thus complicating maintenance and access capabilities.**

3.2 State what happens to a metal during the oxidation step of a REDOX process. What might be the visible changes in the metal?

- **During oxidation, a metal atom loses electrons and becomes a positively charged ion. This chemical change is destructive to the metal and will be seen as corrosion.**

3.3 Define passivity.

Passivity is the buildup of a stable, tenacious layer of metal oxide corrosion products on the surface of a metal that act as a barrier separating the metal surface from the environment, thereby impeding further corrosion.

3.4. Describe how the rate of corrosion is affected by temperature, oxygen, pH, and metal composition.

- **As temperature increases, the rate of corrosion, like most other chemical reactions, increases. Corrosion rate roughly doubles with every 20-50°F temperature rise.**
- **The presence of oxygen increases the corrosion rate by removing the polarizing agent and reacting directly to oxidize the metal.**
- **Corrosion rate is minimized between a pH of roughly 4 and 10. If pH is above or below this range, corrosion rate will generally increase.**
- **Deposits, scales, or irregular surfaces create areas on a metal's surface where local corrosion can initiate and proceed at a faster rate than normal.**

3.5 Identify and describe the action taken for the initial fill of a reactor system to minimize corrosion.

- **Before an initial fill, promote a protective corrosive film by pretreating the reactor system. By controlling the coolant water chemistry and temperature during this process, the barrier created prevents further uncontrolled corrosion.**

3.6 Define crud. List five problems associated with the presence or release of crud into the reactor coolant. List the causes of a crud burst.

- **Crud is insoluble oxide corrosion products suspended in reactor coolant or loosely adhered to metal surfaces.**
- **Problems associated with crud:**
    1. **Fouling of coolant flow paths**
    2. **Fouling of heat transfer surfaces**
    3. **High general background radiation levels**
    4. **Radiation hot spots**
    5. **Radioactive waste disposal**
- **Causes of a crud burst:**
    1. **Increased oxygen concentration**
    2. **Reduced (or significantly changed) pH**
    3. **Large temperature change**
    4. **Physical shock**

3.7 Define galvanic corrosion. List and describe two ways by which galvanic corrosion can be prevented.

- **Galvanic corrosion occurs when two electrochemically dissimilar metals with different potentials are placed in electrical contact in an electrolyte.**
- **Prevention (any two):**
  1. **Cathodic protection – Introduce a sacrificial anode to the metals being protected so that this anode corrodes in place of the protected metal.**
  2. **Chose a relative surface area such that the material to be protected has a larger surface area than the active metal.**
  3. **Separate dissimilar metals with a non-conducting material.**
  4. **Separate the metals from a conductive environment.**
  5. **Use poorly conducting electrolytes (pure water)**

3.8 Define pitting corrosion. State the conditions necessary for pitting corrosion to occur. State the hazards and controls associated with pitting corrosion.

- **Pitting corrosion occurs where the anodic site becomes fixed in a small area and the formation of holes in an otherwise unaffected area takes place.**
- **Conditions: low flow and difference in oxygen concentration**
- **Hazards: rapid penetration of the metal (leak)**
- **Controls: Avoid stagnant conditions**
  Use metals that are less susceptible to pitting
  Avoid agents in the water that cause pitting (such as oxygen)
  Design the system such that no crevices are present

3.9 Define crevice corrosion.

The type of pitting corrosion that occurs specifically within the low flow region of a crevice. (Note: Since "Pitting Corrosion" and "Crevice Corrosion" are so similar, Nuclear Power School groups them together as "Oxygen Pitting and Crevice Corrosion")

3.10 Describe the O_2 pitting and crevice corrosion illustrated in Figure 12.

If a steel (iron alloy) component is exposed to water with dissolved oxygen in it, oxygen pitting and crevice corrosion can occur in a crevice. The iron undergoes general corrosion by reacting with the oxygen in the crevice. Therefore, the oxygen concentration in the crevice decreases. The low flow area prevents mixing, so a concentration cell is set up between the high and low oxygen concentrations. The electrons flow from the region of low oxygen concentration to the region of high oxygen concentration. Oxidation of the metal occurs in the crevice, removing metal and deepening the crevice. Metal ions diffuse out of the crevice, more metal

dissolves, and the process continues. This results in the formation of a pit inside the crevice.

3.11 Answer Question 3.8 for chloride stress corrosion cracking (SCC).

- **Cl^- SCC is an intergranular corrosion that occurs when Cl^- ions are present and the metal is under tensile stress (i.e., force per area that tends to pull objects apart)**
- **Conditions: As with all SCC, the alloy must be susceptible to SCC, the alloy must be exposed to a specific environment, and the alloy must be in a stressed condition. For Cl^- SCC, these conditions are specifically:**
  1. **Austenitic Stainless Steel (a SS that has undergone a specific heat treatment)**
  2. **Cl^- and O_2 present**
  3. **Metal under tensile stress**
- **Hazards: (same as any SCC) rapid crack formation leading to the following:**
  1. **Contamination**
  2. **Loss of coolant**
  3. **Loss of pressure**
- **Controls:**
  1. **Limit $[Cl^-]$ (Chloride concentration in the coolant)**
  2. **Limit $[O_2]$**
  3. **Use different metal (such as low carbon steel)**

3.12 Answer Question 3.8 for caustic stress corrosion cracking.

- **Caustic SCC is an intergranular corrosion where mild steels and stainless steels will crack if exposed to concentrated caustic (high pH) environments with the metal under tensile stress.**
- **Conditions:**
  1. **Localized boiling of a caustic (basic pH) solution**
  2. **Tensile stress**
- **Hazards: (same as any SCC) rapid crack formation leading to the following:**
  1. **Contamination**
  2. **Loss of coolant**
  3. **Loss of pressure**
- **Controls:**
  1. **Use a buffer solution**