CHEMISTRY

1. pH represents the concentration of H\(^+\) ions in a solution, [H\(^+\)] . pH is a log scale base 10 and equal to \(-\log[H^+]\). A pH of 7 is a neutral solution. PH < 7 is acidic and pH > 7 is basic.

2. To determine final pH, determine the total concentration of H\(^+\) ions, and take the log value

\[
\text{pH} = -\log \left[ \frac{2.01 \times 10^{-3} \text{ moles}}{3 \text{ liters}} \right] = 3.17
\]

To determine the final temperature, assume the heat capacity and density of both solutions to be similar, then

\[
\Delta h = c_p \Delta T
\]

\[
m_1 h_1 + m_2 h_2 = m_3 h_3
\]

\[
m_1(c_{p1}T_1) + m_2(c_{p2}T_2) = m_3(c_{p3}T_3)
\]

\[
T_3 = \frac{m_1c_{p1}T_1 + m_2c_{p2}T_2}{m_3c_{p3}} = \frac{\rho_1V_1c_{p1}T_1 + \rho_2V_2c_{p2}T_2}{\rho_3V_3c_{p3}} = \frac{V_1T_1 + V_2T_2}{V_3}
\]

\[
T_3 = \frac{2 \cdot 80 + 1 \cdot 40}{3} = 66.67 \text{ F}
\]

3. Acid-base chemistry is very important because acids have a big influence on living organisms.

4. A quantum model in which electrons move around the nucleus in only certain allowed circular orbits. These orbits depend upon the allowable energy levels available to the electron given by

\[
E = -2.718 \times 10^{-18} \left( \frac{Z^2}{n^2} \right) \text{ Joules}
\]

where n, an integer, is the orbital radius number, and Z is the nuclear charge.

The model is not realistic since electrons do not move around the atomic nucleus in prescribed circular orbits. However, the historic importance of the model is the recognition of the quantization of energy.
5. The formula for sulfur trioxide is \( \text{SO}_3 \). For each sulfur atom, there are 3 oxygen atoms, indicating sulfur is in the +6 oxidation state. Assuming all the sulfur reacts to form sulfur trioxide, the number of sulfur atoms in 500 g is

\[
(500 \text{ g S}) \left( \frac{1 \text{ mol S}}{32.06 \text{ g}} \right) \left( \frac{6.022 \cdot 10^{23} \text{ atoms}}{1 \text{ mol}} \right) = 9.39 \cdot 10^{24} \text{ atoms S}
\]

For each sulfur atom, there are 3 oxygen atoms, thus,

\[
(9.39 \cdot 10^{24} \text{ atoms S}) \left( \frac{3 \text{ atoms O}}{1 \text{ atom S}} \right) \left( \frac{1 \text{ mol}}{6.022 \cdot 10^{23} \text{ atoms}} \right) \left( \frac{16.00 \text{ g}}{1 \text{ mol O}} \right) = 748.5 \text{ g Oxygen}
\]

6. Combining sodium hydroxide (NaOH), a base, with sulfuric acid H\(_2\)SO\(_4\) produces a salt, sodium sulfate (Na\(_2\)SO\(_4\)) and water (H\(_2\)O). The balanced equation can be written as

\[
2\text{NaOH} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}
\]

7. The enthalpy change of the previous reaction is given by

\[
\Delta H_{\text{rxn}} = \sum \Delta H_{\text{products}} - \sum \Delta H_{\text{reactants}}
\]

From a standard thermodynamic data table assuming aqueous solutions,

\[
\Delta H_{f,\text{NaOH}}^0 = -470 \text{ kJ/mol} \quad \Delta H_{f,\text{Na}_2\text{SO}_4}^0 = -1387 \text{ kJ/mol}
\]

\[
\Delta H_{f,\text{H}_2\text{SO}_4}^0 = -909 \text{ kJ/mol} \quad \Delta H_{f,\text{H}_2\text{O}}^0 = -286 \text{ kJ/mol}
\]

\[
\Delta H_{\text{rxn}} = -1387 - 286 - (-470 - 909) = -294 \text{ kJ/mol}
\]

8. Na, sodium has atomic number 11. It is a Group 1A Alkali metal. The electron structure is

\[1s^22s^22p^63s^1\]

9. Yes they will react, and the outcome will be a salt (NaCl) and water (H\(_2\)O). The balanced equation is

\[
\text{NaOH} + \text{HCl} \rightarrow \text{H}_2\text{O} + \text{NaCl}
\]

10. The balanced equation for the combustion of propane (C\(_3\)H\(_8\)) in the presence of oxygen gas (O\(_2\)) is

\[
\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}
\]

Thus, by burning 3 moles of propane, 9 moles of CO\(_2\) will be produced.

11. The mathematical expression for pH is

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

pH is on a scale from 0 (strong acid) to 14 (strong base) with 7 being neutral.
The pH of pure water is 7. If the hydrogen ion concentration increases the pH will decrease. The disassociation constant of water, $K_w$, is defined by

$$2\text{H}_2\text{O}(l) \leftrightarrow \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq)$$

$$K_w = \left[\text{H}_3\text{O}^+\right] \times \left[\text{OH}^-\right]$$

at 25°C $\left[\text{H}^+\right] = \left[\text{OH}^-\right] = 1.0 \times 10^{-7}$ (log$[\text{H}^+] = 7$)

$\therefore K_w = \left[\text{H}^+\right] \times \left[\text{OH}^-\right] = 1.0 \times 10^{-14}$

According to Le Chatelier's principle, if a change is imposed on a system at equilibrium, the position of the equilibrium will shift in a direction that tends to reduce that change. By heating the water, the system will adjust to consume energy and the system will shift to the left (think of energy as a reactant) since the process is endothermic. Thus, if the temperature increases, $K_w$ increases. At 60°C, $K_w = 1.0 \times 10^{-13}$.

12. A rate law for a reaction involving a single reactant, $A$, is an example of a differential equation

$$aA \rightarrow \text{products}$$

Rate = $-\frac{\Delta[A]}{\Delta t} = k[A]^n$

If the reaction is 1st order ($n=1$) then

$$-\frac{DA}{Dt} = k[A]$$

$$-\frac{DA}{[A]} = kDt$$

$\ln[A] = kt + \ln[A_0]$.

$\therefore [A] = [A_0]e^{-kt}$

13. If a reaction produces heat and energy flows out of the system, the process is exothermic. If energy is absorbed from the surroundings, the process is endothermic. Physically, the potential energy in chemical bonds is converted into thermal energy and vice-versa.

14. The rate law for radioactive decay of substances with a half-life, $\lambda$ is

$$N = N_0e^{-kt}$$

$$k = \frac{\ln 2}{\lambda}$$

$$\frac{N}{N_0} = e^{-\frac{\ln 2}{60}} = 0.354$$

Thus, after 60 years, 35.4% is remaining.

15. Ionic bonding occurs when an atom that loses electrons relatively easily reacts with an atom that has a high affinity for electrons. Typically ionic compounds are formed between metals and nonmetals. The bonding force developed is very strong due to the electrostatic attraction of the closely packed oppositely charged ions.
16. Corrosion is the oxidation of a metal. Corrosion of iron produces rust

\[
4\text{Fe}^{2+}(aq) + \text{O}_2(g) + (4 + 2n)\text{H}_2\text{O}(l) \rightarrow 2\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}(s) + 8\text{H}^+(aq)
\]

Copper forms a layer of greenish copper carbonate called patina, and silver tarnish is silver sulfide.

17. An acid is a substance that produces H\(^+\) ions when dissolved in water. A buffer solution is one that resists a change in pH when either [OH\(^-\)] or [H\(^+\)] ions are added. Blood is a good example of a buffer solution as it absorbs acids and bases produced in biological processes.

18. A covalent bond, produced by the attraction of the proton to the electron holds the \text{H}_2 molecule together.

![H-H bond](image)

19. The reaction of iron in HCl produces ferrous chloride and liberates hydrogen gas given by (assuming Fe goes to its 1\(^{st}\) oxidation state)

\[
2\text{HCl}(aq) + \text{Fe}^{2+}(s) \rightarrow \text{H}_2(g) + \text{FeCl}_2(aq)
\]

Thus, 2 moles of HCl dissolve 1 mole of Fe. The number of grams of Fe dissolved by one liter of a 3 M HCl solution is

\[
(1 \text{ liter}) \left( \frac{3 \text{ moles HCl}}{1 \text{ liter}} \right) \left( \frac{1 \text{ mole Fe}}{2 \text{ moles HCl}} \right) \left( \frac{55.85 \text{ g}}{1 \text{ mole Fe}} \right) = 83.8 \text{ g Fe}
\]