Science-1A Lecture: Week-13, Monday, November 1, 2021

Preparation for Quiz 6 which will be passed out November 8

The practice questions and solutions for Quiz 6 at
https://yosemitefoothills.com/Science-1A/QuizAndTestPractice/SampleQuestions-Quiz-6.pdf
and
https://yosemitefoothills.com/Science-1A/QuizAndTestPractice/SampleQuestions-Quiz-6-Solutions.pdf

You will need to use your Periodic Table of Elements at
https://yosemitefoothills.com/Science-1A/Handouts/Week-09/PeriodicTableOfElements.jpg
for the remainder of the course.

As always, know how to find stuff on it and in the Equation Sheet at
https://yosemitefoothills.com/Science-1A/EquationAndSymbolNotes.pdf .

Study this note carefully because you must do the work without any reference to this note while taking Quiz 6. Only a clean Equation sheet is to be used when taking the Quizzes and Tests.

1. (1 points) In the following chemical reaction, the (**reactants**, ~~products~~) are at the left side of the double arrow.

$$2H_2 + O_2 \Rightarrow 2H_2O + \text{energy}$$

Just remember that reactants are at the left side and products are at the right side. When the reaction arrows show it going go both ways (<==>), this terminology is a pointless tradition. In many discussions describing explosions or combustion reactions, the terms reactants and products are useful.

2. (1 point) In the following chemical reaction, the (~~hydrogen and oxygen~~, **water**) molecules are the most tightly held together and therefore are in a lower energy state.

$$2H_2 + O_2 \Rightarrow 2H_2O + \text{energy}$$

Energy was released when the hydrogen and oxygen gas reacted to form the more tightly bound, lower energy water molecules. The excess energy became kinetic energy of the water molecules.

3. (2 points) In the lab, we produced hydrogen and oxygen gases in a plastic bag, but the reaction $2H_2 + O_2 \Rightarrow 2H_2O + \text{energy}$ did not happen even though they were colliding into each other many times every microsecond. This was because at room temperature they did not collide with sufficient speed to

overcome the reaction __**energy**__ __**barrier**__.

The energy barrier is discussed in the October 13 Lab Notes at
https://yosemitefoothills.com/Science-1A/OnlineLectureAndLabNotes/Week-10-Lab-Wednesday-October-13-2021.pdf

4. (5 points) Write the chemical formula that shows how methane gas CH_4 burns in the presence of oxygen O_2 by inserting the smallest, correct 4 numbers and a word at the end space:

$$\underline{\;\mathbf{1}\;}\,\mathbf{CH_4} + \underline{\;\mathbf{2}\;}\,\mathbf{O_2} \Rightarrow \underline{\;\mathbf{1}\;}\,\mathbf{CO_2} + \underline{\;\mathbf{2}\;}\,\mathbf{H_2O} + \underline{\;\textbf{energy}\;}$$

This question and the final two questions below (#46 and #47) are balancing chemical combustion equations. Be sure to study
https://yosemitefoothills.com/Science-1A/OnlineLectureAndLabNotes/Week-12-Lecture-Monday-October-25-2021.pdf
and the handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-11/BalancingChemicalEquations.pdf .

5. (5 points) When a sodium atom loses its outermost electron, it becomes a (**positive**, ~~negative~~) sodium

___**ion**___ and its remaining electrons have a non-reactive structure very similar to that of a __**neon**___ atom.

Electrons have a negative charge. A neutral sodium atom has 11 protons and 11 electrons so losing an electron will leave it with 11 protons, but only 10 electrons, just the number of electrons on a neutral neon atom which is the previous atom in the Periodic Table. The neon atom is perfectly happy with a filled outermost electron shell and is therefore non-reactive. The sodium ion's electrons are happy, but the sodium ion will still bond to other atoms because of its positive net charge.

6. (5 points) When a chlorine atom gains an electron, it becomes a (~~positive~~, **negative**) chlorine ___**ion**___ and

its electrons then have a non-reactive structure very similar to that of a ___**argon**___ atom.

A neutral chlorine atom has 17 protons and 17 electrons. When it gains an additional electron to fill its outermost electron shell, it will have a net negative charge and its electrons will look like those of argon, the next atom in the Periodic Table.

7. (6 points) The three general classes of chemical bonds that hold molecules and crystals together are

__**ionic**__ bonds when the atoms completely lose or gain each other's outermost electrons, __**covalent**__

bonds when adjacent atoms share their outermost electrons, and _**metallic**_ bonds when the outermost

electrons are shared by an entire crystal formed by the atoms.

Questions 8-12 are explained in Lecture at
https://yosemitefoothills.com/Science-1A/OnlineLectureAndLabNotes/Week-09-Lab-Wednesday-October-6-2021.pdf
and at
https://yosemitefoothills.com/Science-1A/Handouts/Week-10/HoldingMatterTogether.pdf .

8. (2 points) Salt crystals NaCl are held together by __**ionic**___ bonds.

9. (2 points) Gold crystals are held together by _**metallic**_ bonds.

10. (2 points) Methane molecules are held together by _**covalent**_ bonds.

Methane is CH_4, and like nearly all carbon molecules, it bonds with covalent bonds.

11. (2 points) Oxygen molecules are held together by _**covalent**_ bonds.

12. (4 points) Water molecules are held together primarily by _**covalent**_ bonding, but it is not evenly

balanced. The shared electrons spend more time around the oxygen atom. This uneven bonding forms what

is called an electric _**dipole**_ moment that turns out to be very important in determining the properties of

water and water solutions.

Water is unusual. For subtle reasons of quantum mechanics, oxygen has its two bonds at an angle of 105° making water molecules have the "Mickey Mouse" appearance. The oxygens pull the electrons away from the hydrogens leaving the hydrogen side with a positive charge and the oxygen side with a negative charge. That creates an unusually strong electric dipole moment which can pull on other atoms and molecules.

13. (2 points) The electromagnetic energy within a microwave oven is transferred to the __**dipole**__ moments

of water molecules in the food causing the food to heat up.

The electric field inside of a microwave oven reverses at a rate of about 2.45 GHz and interacts with the dipole moment of the water molecules which then twist around at that frequency. The twisting energy is transferred to other molecules as the water molecules bump into them. The microwave energy therefore ends up as heat in the food.

Questions 14-18 are a matter of using the Periodic Table to determine the ionic charge and then pairing up the right numbers of oppositely-charged ions to make the total charge zero. Group 1 atoms become ions with a +1 charge and Group 2 atoms become ions with +2 charge. On the other side of the Periodic Table, Group 17 atoms become ions with a -1 charge, Group 16 with a -2 charge. N and P can go either way, -3, or +5. Sulfur usual has -2, but can sometimes have +6. Carbon C usually makes covalent bonds, not ionic bonds, but with oxygen nearby, can it can end up with a +4 charge as in $(CO_3)^{--}$ discussed below.

When putting these ions together Na^+ goes with Cl^- making NaCl, but Ca^{++} (also written as Ca^{+2}) needs 2 Cl^- ions so $CaCl_2$ is the natural combination. Mg is in Group 2 so its ion is Mg^{++} which nicely matches with a single O which is O^{--} since O is in Group 16; that makes MgO. You should now be able to see how this rule works for HF, H_2S and any similar other combinations you might see on a Quiz or Test.

Questions 19-21 are a bit different. The end result is not balanced, but has a net charge. That is because these groups tend to stick together when reacting with other molecules. The are called **polyatomic ions**. Parentheses are usually used to show that the complete group has the indicated charge. For example, the hydroxide ions is should be written as $(OH)^-$, not OH^- as is frequently done. It has a single negative charge because the O is -2 and the H is +1, so it has a net charge of (-2) + 1= -1. $(CO_3)^{--}$ has two negative charges because C is +4 and each O is -2, making 4 + 3(-2) = -2. Similarly, $(NH_4)^+$ has N as -3 and H as +1, so it becomes -3 + 4(+1) = +1.

Other common polyatomic ions are SO_4^{--}, NO_3^-, and PO_4^{---} (also written as PO_4^{-3}). These are parts of the acids H_2SO_4, HNO_3, and H_3PO_4. They are called sulfuric, nitric, and phosphoric acids, respectively. Notice how these have S^{+6}, N^{+5}, and P^{+5}; they lose all their outer electrons to greedy oxygens rather than their normal acquisition of electrons.

With that background, you can now understand Questions 22-24 where polyatomic ions are combined. Here the parentheses are only used when necessary, for example to show that $Mg(OH)_2$ is not $MgOH_2$.

For Questions 25-36, it is really helpful to have played with our molecular models. In lieu of that, pretend that you have carbon balls with 4 holes, nitrogen or phosphorus balls with 3, oxygen or sulfur balls with 2, and chlorine balls with only 1; and then that you are tasked to connect the atoms together without any empty holes left over. Double and triple bonds are done with long, flexible bonds so they can curve around.

Some other molecules that combine nitrogen, phosphorus or sulfur to oxygen, need balls with 5, 5, or 6 holes, respectively. See for example, **hydrochlorothiazide** (my blood pressure medicine) which use 6 bonds to each of its 2 sulfur atoms. It is shown on page 8 of the molecular diagrams handout at
https://yosemitefoothills.com/Science-1A/Handouts/Week-09/AllMolecularStructureImages.pdf
and in an animation at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/Molecules/Hydrochlorothiazide.gif .

The explosives **nitroglycerine** and **trinitrotolulene** (TNT) shown on page 11 of the molecular diagrams handout are also exceptions which use nitrogens with 5 bonds, but when built with balls we use ones with 4 holes. They then end up with a flat structure and a positive charge. They are shown in animations at
https://yosemitefoothills.com/Science-1A/MolecularAnimations/Molecules/Nitroglycerin.gif and
https://yosemitefoothills.com/Science-1A/MolecularAnimations/Molecules/Trinitrotoluene.gif
They do not need any external oxygen to explode since they are built with unstable nitrogen oxides that release energy during an explosion to become tightly-bound N_2 molecules.

For questions 37 and 38, it is useful to review the discussion at
https://yosemitefoothills.com/Science-1A/Handouts/Week-09/SimplifiedMoleculeDiagrams.pdf

Questions 39-45 are about calculating molecular weights, atoms, and moles. For how these are calculated, see the Lecture Note at
https://yosemitefoothills.com/Science-1A/OnlineLectureAndLabNotes/Week-12-Lecture-Friday-October-29-2021.pdf
and the comparison with counting eggs at
https://yosemitefoothills.com/Science-1A/Handouts/Week-12/CalculatingMolecularMasses.pdf

The final two questions are balancing chemical combustion equations. **See the notes above following Question 4.**

You can be sure that the Chemistry Midterm and the Final Exam will have more chemical combustion equation balancing questions similar to questions 46 and 47 here on Quiz 6.

Be sure to learn how to balance these combustion equations!