NS H6 (pg 1 of 2) Reaction Types: Combustion (Always Redox Reactions) Name______________________

Combustion, at its most general, can mean the *fast* reaction of oxygen gas (O_2) with any substance (that serves as a fuel) usually producing heat and light (flame) and always oxide products.

Generic reaction: $X + O_2 \rightarrow X_?O_? + \text{Energy}$

All combustion reactions are redox reactions.

Burning Organic Compounds

Our society depends on energy, which we get primarily from combustion of very particular types of compounds called organic compounds (any compound containing carbon). So most commonly we will use the term combustion to mean the reaction of oxygen with a compound containing carbon and hydrogen, and maybe oxygen as well. These compounds fall into two general categories:

- hydrocarbons (C, H compounds)
- carbohydrates (C, H, O compounds in which the H and O are present in a 2:1 ratio)
- various other organic compounds such as alcohols, oils, proteins, etc that are carbon based compounds

A common synonym for combustion is "burn". Uncontrolled combustion happening VERY rapidly would be an explosion.

Written using generic symbols, combustion of organic compounds could be shown as:

$$C_xH_y + O_2 \rightarrow CO_2 + H_2O + \text{Energy}$$

An important hint when balancing combustion equations is to always balance the oxygen last.

These are some unbalanced examples – take time to practice balancing. (answers on the back)

a. methane $CH_4 + O_2 \rightarrow CO_2 + H_2O$

b. ethane $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

c. sugar $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

d. ethyl alcohol $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$

Burning Compounds that contain more than just C H O

Notice that when burning hydrocarbons and carbohydrates the products are all the same, in every reaction. Some carbon hydrogen, oxygen compounds may also contain other elements. When you burn these types of compounds, the other elements end up as oxides also. Burning compounds that contain nitrogen (burns to form NO_2) or sulfur (burns to form SO_2).

These are some unbalanced examples - take the time to practice balancing. (answers on the back)

e. $C_{21}H_{24}N_2O_4 + O_2 \rightarrow CO_2 + H_2O + NO_2$

f. $C_2H_5SH + O_2 \rightarrow CO_2 + H_2O + SO_2$

Burning Compounds that don't contain any C H or O

Other substances that don't contain carbon, hydrogen or oxygen can be burned. In class we have burned magnesium. Since there is no carbon or hydrogen present, water and carbon dioxide cannot be products. Instead the product is magnesium oxide (note that the product is MgO, because magnesium is Mg^{2+} and oxygen is O^{2-}).

Here are some unbalanced examples - take the time to practice balancing. (answers on the back)

g. $Mg + O_2 \rightarrow MgO$ (unbalanced - take the time to practice balancing)

h. $Fe + O_2 \rightarrow Fe_2O_3$ (unbalanced - take the time to practice balancing)

Incomplete Combustion

There are still more complexities with the concept of combustion as you probe even deeper. Sometimes all of the carbon in the fuel can't "get" all of the oxygen that the compound would like to bond with. For example, an inefficient combustion caused by not having enough oxygen or occurring low burn temperatures, may yield the usual products, CO_2 and H_2O as well as carbon monoxide, CO and elemental carbon (soot), C. It is impossible to balance an incomplete combustion because there is no way of knowing in what ratio each of the carbon monoxide, carbon, and carbon dioxide forms. In all of the reactions that you write in this first-year chemistry course, unless told otherwise, you can assume "complete" combustion occurs.

So why is carbon monoxide SO dangerous?

Actually, carbon monoxide is no more toxic to your cells than carbon dioxide, however, if you are exposed to a mix of air that contains even very small quantities of carbon monoxide, the hemoglobin on your red blood cells will preferentially choose carbon monoxide NOT oxygen gas. This will mean that you would be asphyxiated much faster when carbon monoxide is in the mix, than when exposed to a mix of gases that contains air and carbon dioxide.

Answers to unbalanced examples

a. $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

b. sometimes with combustion reactions, there will be an odd number of oxygen atoms on the product side, but the O_2 on the reactant side makes it difficult to make the number of oxygen atoms odd. The trick is to balance the equation with a fraction – note the 9.5 in front of the O_2 and then multiply every coefficient (the numbers in front of each compound) by 2 to result in all whole number coefficients.

- $C_2H_6 + 3.5\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$
- $2 \times (\ C_2H_6 + 3.5\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O\ )$
- **final answer $2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$

c. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

d. $C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$

e. $C_{21}H_{24}N_2O_4 + 27\ O_2 \rightarrow 21\ CO_2 + 12\ H_2O + 2\ NO_2$

f. this is another one of those reactions that results in an odd number of oxygen atoms

- $C_2H_5SH + 4.5\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O + SO_2$
- $2 \times (\ C_2H_5SH + 4.5\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O + SO_2\ )$
- **final answer $2\ C_2H_5SH + 9\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O + 2\ SO_2$

g. $2\ Mg + O_2 \rightarrow 2\ MgO$

h. $4Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$