

# 5. Chemical Equations

## 5.1 Introduction

Chemical equations are very important in chemistry. The ability to write and balance chemical equations makes the study of chemistry very easy and interesting. It is therefore very important that students should learn to write and balance chemical equations quite early in their study of the subject.

This is the best time to learn it. The writing and balancing of chemical equations is learnt and perfected by constant practice. You cannot achieve it by memorization!

## 5.2 What is chemical equation?

Chemical equation is the shorthand language of chemistry. In a chemical equation, the reactants are placed on the left hand side of the arrow while the products are placed on the right

Reactant → Products.

The reactants and products may be elements, ions or compounds. The equation tells us how many moles of the reactant(s) react to give a given number of moles of the products(s). The conditions under which the reaction occurs may be written on top of the arrow. The physical states of the reactants and products are at times indicated with the notations, (s), (l), (g) or (aq) written to the immediate right of the symbols or formulae of the reactants and products. For example,



A chemical equation does not give information on the rate of the chemical reaction.

## 5.3 What you must know to be able to write balanced equations

To be able to write balanced equations at this stage, the student should know:

- the symbols and names of the first twenty elements of the periodic table, as well as those of other common elements.

- (ii) the combining powers of common ions and radicals.
- (iii) the names of common compounds.
- (iv) how to write the formulae of compounds using knowledge of the combining powers of the constituent elements or ions.
- (v) common types of chemical reactions and their usual products.

## 5.4 Combining powers of ions and radicals

The symbols and names of common elements of the periodic table was treated in Chapter 2.

The combining power of each of these elements is equal to the number of electrons gained or lost by the atom in ionic bonding, or contributed by each atom for sharing in covalent bonding.

Elements in group 1 of the periodic table have one electron in their outermost shells which they readily lose during chemical bonding to form ions. So they have combining powers of +1. Examples are sodium ion,  $\text{Na}^+$ , and potassium ions,  $\text{K}^+$ . Group II metals lose two electrons, hence the ions of beryllium  $\text{Be}^2+$ , magnesium,  $\text{Mg}^{2+}$ , and calcium,  $\text{Ca}^{2+}$ , have combining powers of +2. Metallic ions usually have positive combining powers and are called **cations**.

Non-metals usually gain electrons during chemical bonding to form ions. They have negative combining powers and are called **anions**. Non-metals of group VII (fluorine, chlorine, bromine, iodine), gain one electron in chemical bonding, and thus have combining powers of -1. Oxygen and sulphur have combining powers of -2.

A list of the combining powers of common elements and radicals is given in

TABLE 5.1 The combining powers of ions and radicals

Name of Ion	Symbol of Ion	Charge/Combining Power
Cations		
Hydrogen	$\text{H}^+$	+ 1
Sodium	$\text{Na}^+$	+ 1
Potassium	$\text{K}^+$	+ 1
Ammonium	$\text{NH}_4^+$	+ 1
Magnesium	$\text{Mg}^{2+}$	+ 2
Calcium	$\text{Ca}^{2+}$	+ 2
Zinc	$\text{Zn}^{2+}$	+ 2

Copper (I) and Copper (II)	$\text{Cu}^+$ and $\text{Cu}_{2+}$	+ 1 and + 2
Iron (II) and Iron (III)	$\text{Fe}^{2+}$ and $\text{Fe}^{3+}$	+ 2 and + 3
Mercury (I) and Mercury (II)	$\text{Hg}^+$ and $\text{Hg}^{2+}$	+ 1 and + 2
Lead (II) and Lead (IV)	$\text{Pb}^{2+}$ and $\text{Pb}_{4+}$	+ 2 and + 4
Tin (II)and Tin (IV)	$\text{Sn}^{2+}$ $\text{Sn}^{4+}$	+ 2 and + 4
Silver	$\text{Ag}^+$	+ 1
Aluminium	$\text{Al}^{3+}$	+ 3
Barium	$\text{Ba}^{2+}$	+ 2
Anions		
Fluoride	$\text{F}^-$	-1
Chloride	$\text{Cl}^-$	-1
Bromide	$\text{Br}^-$	-1
Iodide	$\text{I}^-$	-1
Hydride	$\text{H}^-$	-1
Hydroxyl	$\text{OH}^-$	-1
Oxide	$\text{O}^{2-}$	-2
Sulphide	$\text{S}^{2-}$	-2
Trioxonitrate (III)	$\text{NO}_2^-$	-1
Trioxonitrate (V)	$\text{NO}_3^-$	-1
Hydrogen tetraoxosulphate (VI)	$\text{HSO}_4^-$	-1
Tetraoxosuiphate (VI)	$\text{SO}_4^{2-}$	-2
Hydrogen trioxosulphate (IV)	$\text{HSO}_3^-$	-1
Trioxosulphate (IV)	$\text{SO}_3^{2-}$	-2
Hydrogen trioxocarbonate (IV)	$\text{HCO}_3^-$	-1
Trioxocarbonate (IV)	$\text{CO}_3^{2-}$	-2
Nitride	$\text{N}^{3-}$	-3
Trioxophosphate (III)	$\text{PO}_3^{3-}$	-3

## 5.5 Names and formulae of some common chemical compounds

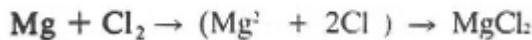
	<b>Names</b>	<b>Formulae</b>
Common Acids	Hydrogen chloride acid (hydrochloric acid) Trioxonitrate(V) acid Tetraoxosulphate(VI) acid Trioxocarbonate(IV) acid	HCl HNO <sub>3</sub> H <sub>2</sub> SO <sub>4</sub> H <sub>2</sub> CO <sub>3</sub>
Common Hydroxides	Sodium hydroxide Potassium hydroxide Calcium hydroxide Copper(II) hydroxide Aluminium hydroxide	NaOH KOH Ca(OH) <sub>2</sub> Cu(OH) <sub>2</sub> Al(OH) <sub>3</sub>
Common Trioxocarbonates (IV)	Calcium trioxocarbonate(IV) Sodium trioxocarbonate(IV) Zinc trioxocarbonate(IV) Potassium trioxocarbonate(IV)	CaCO <sub>3</sub> Na <sub>2</sub> CO <sub>3</sub> ZnCO <sub>3</sub> K <sub>2</sub> CO <sub>3</sub>
Common Oxides	Calcium oxide Sodium oxide Iron(II) oxide Iron(III) oxide Magnesium oxide Zinc oxide Aluminium oxide	CaO Na <sub>2</sub> O FeO Fe <sub>2</sub> O <sub>3</sub> MgO ZnO Al <sub>2</sub> O <sub>3</sub>
Common Salts	Sodium chloride Sodium trioxonitrate(V) Sodium tetraoxosulphate(VI) Calcium chloride Calcium trioxonitrate(V) Calcium tetraoxosulphate(VI) Potassium chloride Potassium trioxonitrate(V) Potassium tetraoxosulphate(VI) Magnesium chloride Magnesium	NaCl NaNO <sub>3</sub> Na <sub>2</sub> SO <sub>4</sub> CaCl <sub>2</sub> Ca(NO <sub>3</sub> ) <sub>2</sub> CaSO <sub>4</sub> KCl KNO <sub>3</sub> K <sub>2</sub> SO <sub>4</sub> MgCl <sub>2</sub> MgSO <sub>4</sub> NH <sub>4</sub> Cl

tetraoxosulphate(VI)	NH <sub>4</sub> NO <sub>3</sub>
Ammonium chloride	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>
Ammonium trioxonitrate(V)	FeCl <sub>2</sub>
Ammonium	FeCl <sub>3</sub>
tetraoxosulphate(VI)	FeSO <sub>4</sub>
Iron(II) chloride	Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>
Iron(III) chloride	Fe(NO <sub>3</sub> ) <sub>3</sub>
Iron(II) tetraoxosulphate(VI)	AlCl <sub>3</sub>
Iron(III) tetraoxosulphate (VI)	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>
Iron(III) trioxonitrate(V)	CuCl <sub>2</sub>
Aluminium chloride	CuSO <sub>4</sub>
Aluminium	ZnCl <sub>2</sub>
tetraoxosulphate(VI)	ZnSO <sub>4</sub>
Copper(II) chloride	
Copper(II)	
tetraoxosulphate(VI)	
Zinc chloride	
Zinc tetraoxosulphate(VI)	

## 5.6 Writing the formulae of compounds by using the combining powers of elements, ions and radicals

In the formation of ionic compounds, the number of cations and anions which combine to form one molecule of the compound must be such as to confer electrical neutrality on the compound. To achieve this, the total number of positive charges on the cations must balance that of the negative charges on the anions.

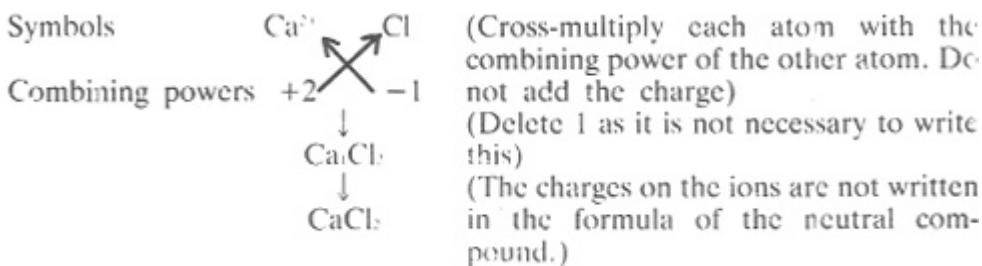
The following equations illustrate the balancing of opposite charges in the formation of sodium chloride and magnesium chloride.



To write the formula of a compound, the symbol of the metal is written first before that of the non-metal. If the compound contains other non-metals in addition to oxygen, the symbol for oxygen is written last. If fluorine is present with oxygen, its symbol is usually written after that of oxygen. We shall discuss the reasons for these later.

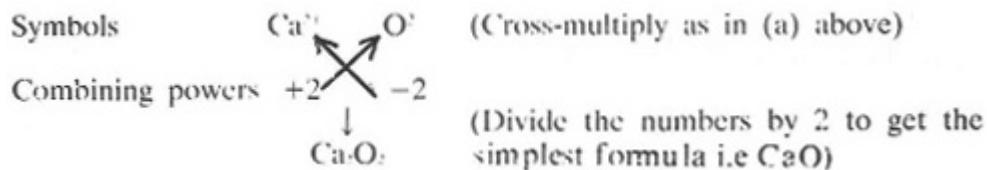
### Examples

(a) To write the formula of calcium chloride “



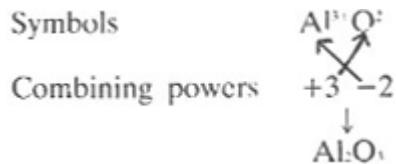
*The formula for calcium chloride is  $\text{CaCl}$*

(b) Formula of calcium oxide



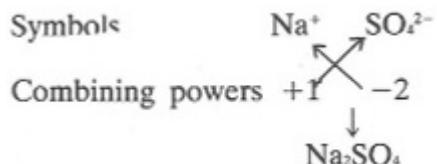
*The formula of calcium oxide is  $\text{CaO}$*

(c) Formula of aluminium oxide



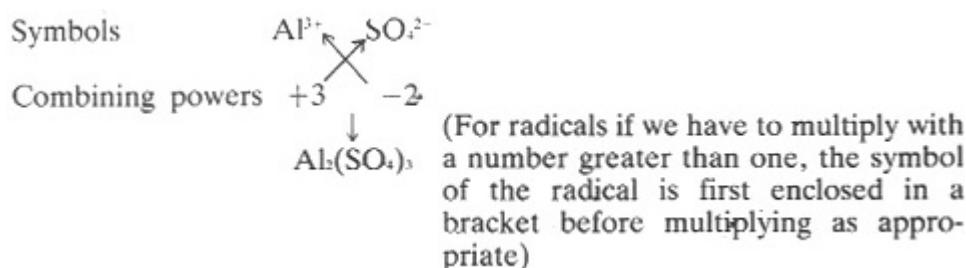
*The formula of aluminium oxide is  $\text{Al}_2\text{O}_3$*

(d) Formula of sodium tetraoxosuiphate(VI)



*The formula of sodium tetraoxosulphate(VI) is  $\text{Na}_2\text{SO}_4$*

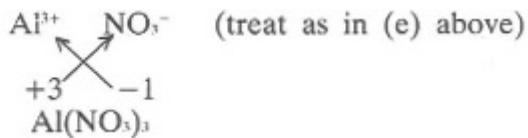
(e) Formula of aluminium tetraoxosulphate(VI)



*The formula of aluminium tetraoxosulphate(VI) is  $\text{Al}_2(\text{SO}_4)_3$*

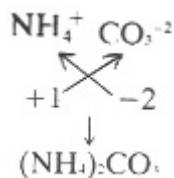
(f) Formula of aluminium trioxonitrate(V)

Symbols

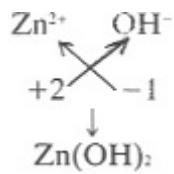


The formula of aluminium trioxonitrate(V) is  $\text{Al}(\text{NO}_3)_3$

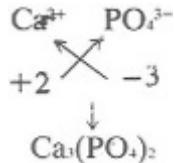
(g) Formula of ammonium trioxocarbonate(IV)



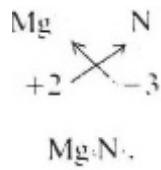
(h) Formula of zinc hydroxide



(i) Formula of calcium tetraoxophosphate(V)



(j) Formula of magnesium nitride



### Exercise 5

Write the formula of the following compounds:

- (i) Tetraoxosulphate(VI) acid.
- (ii) Trioxocarbonate (IV)acid.
- (iii) Potassium hydroxide
- (iv) Calcium hydroxide
- (v) Aluminium hydroxide
- (vi) Sodium trioxocarbonate(IV)
- (vii) Zinc trioxocarbonate(IV)

- (viii) Potassium oxide
- (ix) Magnesium oxide
- (x) Iron(III) oxide
- (xi) Sodium trioxonitrate(V)
- (xii) Potassium tetraoxosulphate(VI)
- (xiii) Calcium trioxonitrate(V)
- (xiv) Ammonium tetraoxosulphate(VI)
- (xv) Magnesium chloride
- (xvi) Copper (II) tetraoxosulphate (VI)
- (xvii) Iron (II) chloride
- (xviii) Iron (III) tetraoxosulphate(VI).
- (xix) Aluminium trioxonitrate(V)

## 5.7 Some common chemical reactions

- (a) Metal + Oxygen  $\rightarrow$  Metallic oxide.
- (b) Metal + Sulphur  $\rightarrow$  Metallic sulphide.
- (c) Metal + Halogen  $\rightarrow$  Metallic halide.
- (d) Metal + Acid (dilute)  $\rightarrow$  Salt + Hydrogen.
- (e) Non-metal + Oxygen  $\rightarrow$  Non-metallic oxide.
- (f) Alkali metal + Water  $\rightarrow$  Alkali hydroxide + Hydrogen.
- (g) Acidic oxide of a non-metal + Water  $\rightarrow$  Acid.
- (h) Alkali metal oxide + Water  $\rightarrow$  Alkali hydroxide.
- (i) Hydroxide + Acid  $\rightarrow$  Salt + Water.
- (j) Metallic Oxide + Acid  $\rightarrow$  Salt + Water.
- (k) Trioxocarbonate (IV) + Acid  $\rightarrow$  Salt + Carbon(IV) oxide + Water.

## 5.8 Writing and balancing of chemical equations

When writing chemical equations with symbols, atoms and molecules should be written to denote the way the elements or compounds occur in nature. For example oxygen, hydrogen, fluorine, chlorine, bromine, iodine and nitrogen which are all **diatomic** should be written as  $O_2$ ,  $H_2$ ,  $F_2$ ,  $Cl_2$ ,  $Br_2$ ,  $I_2$  and  $N_2$  respectively. Metals are all **monoatomic**.

The correct formulae of the reactants and products are first written. The equation is then balanced by ensuring that the number of

atoms/ions of each element in the reactant(s) is equal to the number of its atoms/ions in the product(s). This may be achieved when necessary, by multiplying the symbol(s) or formula(e) of one or more elements or compounds with appropriate small whole numbers to increase the number of atoms of particular element(s) in the reactant(s) or product(s). The numbers are written directly to the left of the symbols or formulae.

### *Examples*

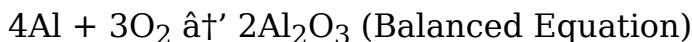
#### **(a) Metal + Oxygen → Metallic oxide**

- (i) Sodium + Oxygen → Sodium oxide.



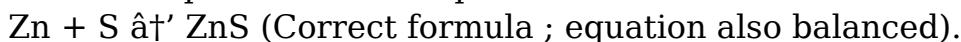
$4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$  (Balancing “ $\rightarrow$ ” by multiplying the number of sodium atoms in the reactant by four, and the molecules of the product, by two).

- (ii) Aluminium + Oxygen → Aluminium oxide.



#### **(b) Metal + Sulphur → Metallic sulphide.**

- (i) Zinc + Sulphur → Zinc sulphide.



- (ii) Potassium + Sulphur → Potassium sulphide

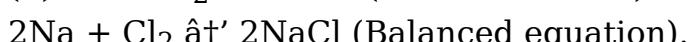


#### **(c) Metal + Halogen → Metallic halide.**

- (i) Copper + Chlorine → Copper(II) chloride

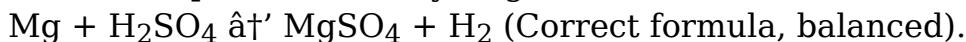


- (ii) Na + Cl<sub>2</sub> → NaCl (correct formula)

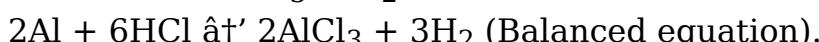


#### **(d) Metal + Acid (dilute) → Salt + Hydrogen.**

- (i) Magnesium + Tetraoxosulphate(VI) acid → Magnesium tetraoxosulphate(VII) + Hydrogen.



- (ii) Al + HCl → AlCl<sub>3</sub> + H<sub>2</sub> (Correct formula).



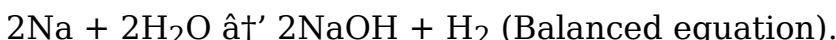
#### **(e) Non-metal + Oxygen → Non-metallic oxide.**

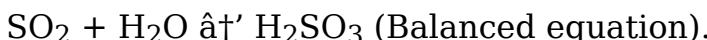
Carbon + Oxygen → Carbon(IV) oxide



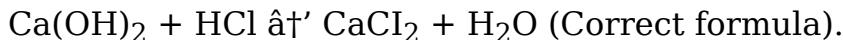
#### **(f) Alkali metal + Water → Alkali hydroxide + Hydrogen.**

Sodium + Water → Sodium hydroxide + Hydrogen.

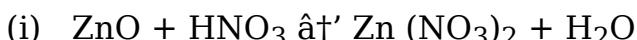


**(g) Acidic oxide + Water  $\rightarrow$  Acid****(h) Alkali metal oxide + Water  $\rightarrow$  Alkali hydroxide.****(i) Hydroxide + Acid  $\rightarrow$  Salt + Water.**

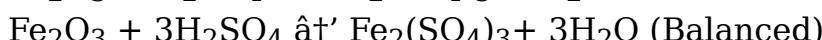
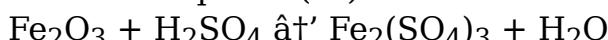
(i) Calcium hydroxide + Hydrogen chloride acid (Hydrochloric acid)  $\rightarrow$  Calcium chloride + water.



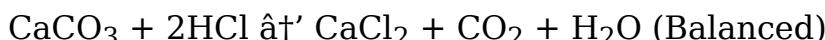
(ii) KOH + H<sub>2</sub>SO<sub>4</sub>  $\rightarrow$  K<sub>2</sub>SO<sub>4</sub> + H<sub>2</sub>O (Correct formula).

**(j) Metallic oxide + Acid  $\rightarrow$  Salt + Water.**

(ii) Iron(III) oxide + Tetraoxosulphate(VI) acid  $\rightarrow$  Iron(III) Tetraoxosulphate (VI) + Water

**(k) Trioxocarbonate(IV) + Acid  $\rightarrow$  Salt + Carbon(IV) oxide + Water**

(i) Calcium trioxocarbonate(IV) + Hydrogen chloride acid (Hydrochloric acid)  $\rightarrow$  Calcium chloride + Carbon(IV) oxide + Water.



(ii) Na<sub>2</sub>CO<sub>3</sub> + H<sub>2</sub>SO<sub>4</sub>  $\rightarrow$  Na<sub>2</sub>SO<sub>4</sub> + CO<sub>2</sub> + H<sub>2</sub>O (Balanced)

*Exercise 5 B**Write balanced equations for the following reactions:*

(a) Calcium + Oxygen

(b) Aluminium + Sulphur

(c) Zinc + Fluorine

(d) Zinc + Hydrogen chloride acid (Hydrochloric acid)

(e) Hydrogen + Oxygen

(f) Calcium + Water

(g) Carbon(IV) oxide + Water

(h) Aluminium hydroxide + Tetraoxosulphate(VI) acid

(i) Copper(II) hydroxide + Trioxonitrate(V) acid

(j) Sodium oxide + Trioxonitrate(V) acid

- (k) Iron(III) oxide + Tetraoxosulphate(VI) acid
- (l) Zinc trioxocarbonate(IV) + Hydrogen chloride acid (Hydrochloric acid)
- (m) Potassium trioxocarbonate(IV) + Trioxonitrate(V) acid.

## Chapter Summary

To be able to write chemical equations the student must know:

- (i) the symbols and names of the common elements and radicals.
- (ii) the combining powers of these common elements and radicals.
- (iii) the names of common compounds.
- (iv) how to write the formulae of compounds by using the combining powers of elements, ions and radicals.
- (v) Types and products of common chemical reactions.

In writing a chemical equation, first write the correct formulae of the reactants and the products. The final step involves the balancing of the equation by making sure that the number of atoms of each element in the reactants is equal to the number of atoms in the products.

## Assessment

1. Write balanced equations for the reactions between:
  - (i) zinc and hydrogen chloride acid (hydrochloric acid)
  - (ii) sodium and water
  - (iii) ethanol and sodium
  - (iv) calcium trioxocarbonate(IV) and hydrogen chloride acid (hydrochloric acid)
  - (v) magnesium hydroxide and tetraoxosulphate(VI) acid
  - (vi) iron and steam
  - (vii) sodium trioxocarbonate(IV) and tetraoxosulphate(VI) acid
  - (viii) iron(III) oxide and tetraoxosulphate(VI) acid
  - (ix) zinc oxide and trioxonitrate(V) acid
  - (x) aluminium and hydrogen chloride acid (hydrochloric acid)
2. Balance the following equations:
  - (i)  $\text{CaCO}_3(\text{s}) + \text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
  - (ii)  $\text{CH}_4(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
  - (iii)  $\text{H}_3\text{PO}_4(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{Na}_2\text{HPO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l})$
  - (iv)  $\text{Cu}(\text{s}) + \text{HNO}_3(\text{aq}) \rightarrow \text{Cu}(\text{NO}_3)(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{NO}(\text{g})$
  - (v)  $\text{Cu}(\text{s}) + \text{HNO}_3(\text{aq}) \rightarrow \text{Cu}(\text{NO}_3)(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{NO}_2(\text{g})$
3. What is the combining power of:
  - (i) Tin in  $\text{SnCl}_4$

- (ii) Copper in  $\text{CuCl}_2$
  - (iii) magnesium in  $\text{MgSO}_4$
  - (iv) lead in  $\text{PbO}$
  - (v) lead in  $\text{PbO}_2$
  - (vi) mercury in  $\text{Hg}_2\text{Cl}_2$
4. When the trioxonitrate(V) salt of an alkali metal M is heated, the formula of the solid product formed is  
(a)  $\text{MO}_2$ ; (b)  $\text{M}_2\text{O}_3$ ; (c)  $\text{MNO}_2$ ; (d)  $\text{M}_2\text{O}$ ; (e)  $\text{M}(\text{NO}_2)_2$
- (WAEC)
5. Which of the following equations represents the combustion of a hydrocarbon in a plentiful supply of air?
- A.  $\text{C}_2\text{H}_4(\text{g}) + 2\text{O}_2 \rightarrow 2\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$
  - B.  $\text{CH}_4(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{C}(\text{s}) + 2\text{H}_2\text{O}(\text{g})$
  - C.  $2\text{C}_2\text{H}_2(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 4\text{CO}(\text{g}) + 2\text{H}_2\text{O}(\text{g})$
  - D.  $2\text{C}_3\text{H}_6(\text{g}) + 7\text{O}_2(\text{g}) \rightarrow 6\text{CO}(\text{g}) + 8\text{H}_2\text{O}(\text{g})$
  - E.  $2\text{C}_2\text{H}_8(\text{g}) + 7\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})$
- (WAEC).