

Carbon and its compounds

Carbon exists in 3 allotropic forms, diamond, graphite and amorphous carbon (charcoal, lampblack, soot and coke) diamond and graphite are crystalline while amorphous carbon is non crystalline.

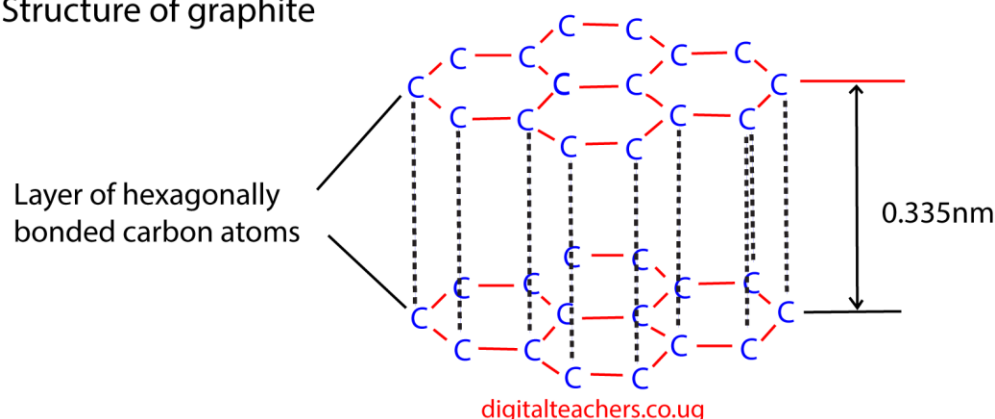
Allotropy is the existence of an element in more than one form without change of state

a. Graphite

In graphite, each carbon atom is covalently bonded to 3 carbon atoms to form a layer of hexagons. Each layer is bonded to another by weak van der Waal forces.

Structure of graphite

Structure of graphite



Properties of graphite as a result of its structure

1. Has open structure and low density.
2. It is slippery and used as a lubricant.
3. Has un-bonded that is free to move about making graphite a good conductor of electricity and heat

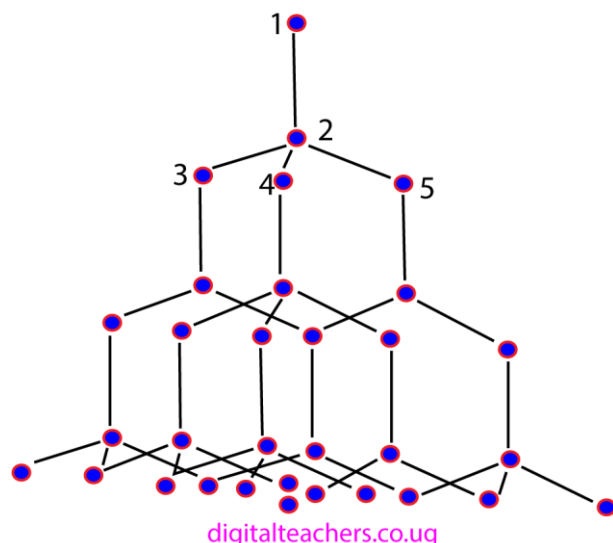
Uses of graphite

1. Manufacture of lead pencil
2. As lubricant

(b) Diamond

Structure of diamond

Each carbon atom is bonded tetrahedrally to four carbon atoms to form a 3D compact structure by strong covalent bonds as shown below. As a result, diamond has a high density, melting and boiling point. It is the hardest substance known.



Diamond is used as an ornament, and to drill, glass cutters and cut other substances.

Differences between diamond and graphite

Graphite

Density of graphite is lower 2.3 g cm^{-3}

Soft

Slippery

Conducts electricity

Diamond

Density of diamond is 3.5 g cm^{-3}

hard

Not slippery

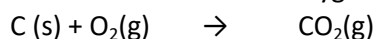
Does not conduct electricity

Experiment to show that graphite and diamond are both allotropes of carbon

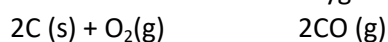
Equal masses of graphite and diamond burn in oxygen to give equal volume/mass of oxygen

Properties of carbon

1. Carbon burns in excess oxygen to form carbon dioxide

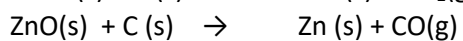


2. Carbon burns in limited oxygen to form carbon monoxide

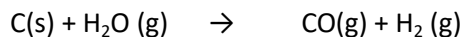


3. Carbon reduce oxides of metals (lead, copper, zinc, iron) to metals





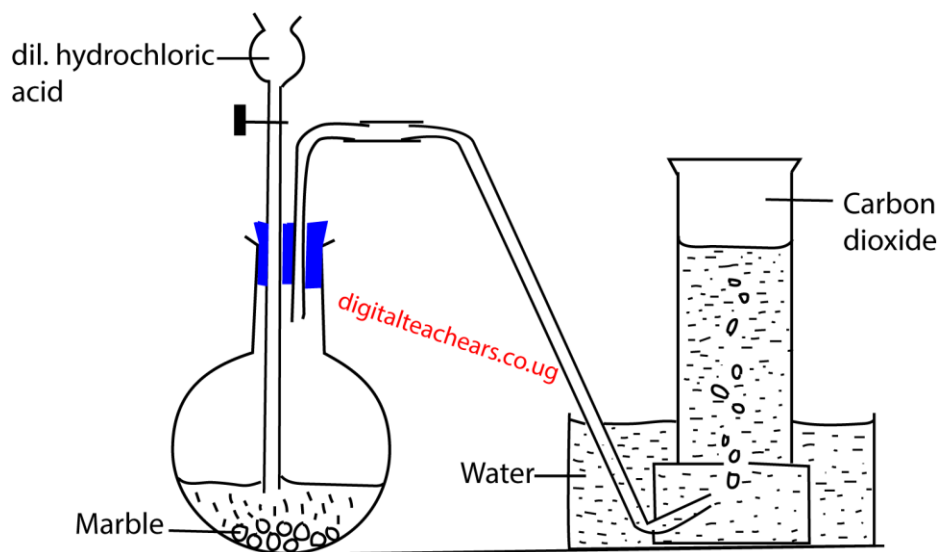
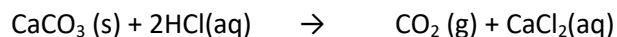
4. At high temperature carbon reacts with steam to form water gas [$\text{CO(g)} + \text{H}_2\text{(g)}$]



Carbon dioxide

Preparation

By reaction between calcium carbonate (marble) and dilute hydrochloric acid.



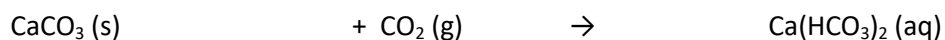
Testing for carbon dioxide

Carbon dioxide form white precipitates with lime water. The white precipitate turns colorless with excess carbon dioxide

Calcium hydroxide + carbon dioxide give calcium carbonate (white ppt.) + water

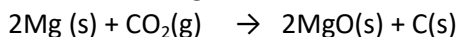


Calcium carbonate (white ppt) + carbon dioxide (excess) give calcium hydrogen carbonate (colorless solution)



Properties of carbon dioxide

1. It is colorless
2. Denser than air
3. Odorless
4. Slightly soluble in water to form an acid solution
5. Extinguishes burning splint
6. Reacts with magnesium to form black specks



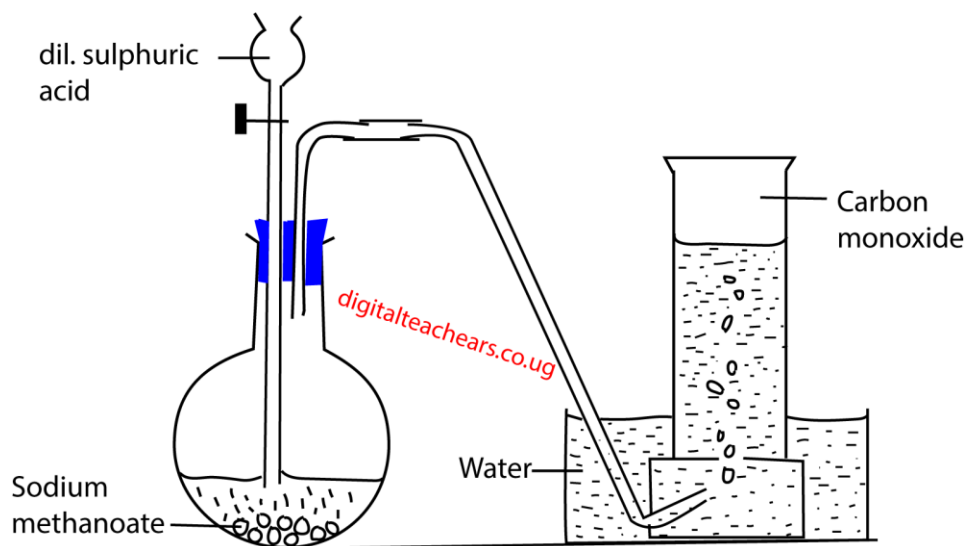
Uses of carbon dioxide

1. In soda
2. In fire extinguishers because it is nonflammable and denser than air thus displaces oxygen from burning item.
3. It is a coolant

Carbon monoxide

Preparation

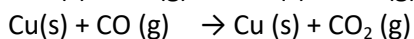
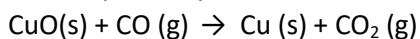
By reacting sodium methanoate with concentrated sulphuric acid



Properties of carbon monoxide

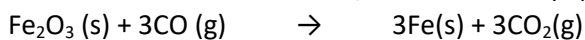
1. Very poisonous, it is produced by incomplete combustion of carbon therefore cooking on *sigiri* should be done when the door and the windows are open to allow in enough air.
2. Has no action on litmus paper
3. Burns with a blue flame
4. Reduce metallic oxides

For example, it reduces black copper oxide and orange lead (II) oxide to brown copper and grey lead respectively



Uses of carbon monoxide

1. It is used in extraction of iron; it reduces iron (III) oxide to Iron



Carbonates

Carbonates are derivatives of carbonic acid, H_2CO_3 .

Properties of carbonate are given in the table below

metal	Formula of carbonate	solubility	Effect of heat	Reaction with acid
K	K ₂ CO ₃	soluble	Do not decompose	Produce carbon dioxide
Na	Na ₂ CO ₃			
Ca	CaCO ₃	insoluble	Decompose into oxides and carbon dioxide	
Mg	MgCO ₃			
Al	Does not form carbonate			
Zn	ZnCO ₃			
Fe	FeCO ₃			
Pb	PbCO ₃			
Cu	CuCO ₃			

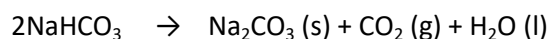
Test for carbonate

All carbonates react with nitric acid to produce carbon dioxide with turn lime water milky.

Hydrogen carbonate

It is only group 1 elements (K, Na) that form solid hydro carbonates.

Hydro carbonates decompose on heating liberating carbon dioxide



Exercise

Questions 1 to 12 circle the correct alternative

1. Which one of the following carbonates is not produced by precipitation method?
 - A. Magnesium carbonate
 - B. Zinc carbonates
 - C. Lead (II) carbonate
 - D. Ammonium carbonate
2. Which of the following pairs of compounds is suitable for preparing carbon dioxide
 - A. Sulphuric acid and lead carbonate
 - B. Hydrochloric acid and lead carbonate
 - C. Sulphuric acid and calcium carbonate
 - D. Hydrochloric acid calcium carbonate
3. Which one of the following is a property of carbon dioxide? It
 - A. It is less dense than air
 - B. It is neutral to litmus paper
 - C. It reacts with sulphuric acid
 - D. It reacts with burning magnesium
4. Which of the following allotropes of carbon conducts electricity?
 - A. Diamond
 - B. Graphite
 - C. Coal
 - D. Coke
5. Which of the following is not a property of carbon monoxide
 - A. Is insoluble in water
 - B. Reduces copper (II) oxide to copper
 - C. Burns in air
 - D. Turns lime water milky.
6. Which one of the following properties is not shown by carbon monoxide
 - A. It pollutes the atmosphere
 - B. It is insoluble in water
 - C. It is a reducing agent
 - D. It is acid oxide
7. Which of the following substances is formed when magnesium burns in carbon in carbon dioxide
 - A. Magnesium carbonate
 - B. Magnesium nitride
 - C. Carbon monoxide
 - D. Carbon
8. Which of the following process is not involved in carbon cycle?
 - A. Respiration
 - B. Combustion
 - C. Photosynthesis
 - D. lightening

9. Which one of the following substances conducts electricity?
- Iodine
 - Graphite
 - Methylbenzene
 - tetrachloromethane
10. Which of the following is not a property of carbon dioxide?
- It is slightly soluble in water
 - It forms a precipitate with lime water
 - It extinguishes burning magnesium
 - It sublimes when solid
11. Which of the gases reduces hot copper (II) oxide to copper?
- Carbon dioxide
 - Carbon monoxide
 - Nitrogen dioxide
 - Nitrogen monoxide
12. Which of the following is not acidic oxide
- Carbon dioxide
 - Carbon monoxide
 - Sulphur dioxide
 - Phosphorus (V) oxide

Each of the questions 13 to 16 consist of an assertion (statement) on the left hand side and a reason on the right hand side.

Select

- If both assertion and reason are true statements and the reason is a correct explanation of the assertion.
- If both assertion and reason are true statements and the reason is **not** a correct explanation of the assertion
- If the assertion is true but the reason is not correct statement.
- If the assertion is not correct but the reason is a correct statement.

Instruction summarized

Assertion	
A. True	True and a correct explanation
B. True	True but not a correct explanation
C. True	Incorrect
D. Incorrect	Correct

- | | | | |
|-----|---|---------|---|
| 13. | A piece of magnesium continues to burn in a jar of carbon dioxide | Because | Carbon dioxide contains two atoms of oxygen |
| 14. | Carbon dioxide and carbon monoxide | Because | Both are reducing agents |

- are pollutants
- | | | | |
|-----|---|---------|---|
| 15. | Graphite and diamond show different chemical properties | Because | Graphite and diamond are allotropes of carbon |
| 16. | Methane burns in air to form carbon dioxide and water | Because | It contains carbon and hydrogen atoms |

In each of the questions 17 to 23 one or more of the answers given may be correct. Read each questions carefully and then indicate the correct answer according to the following

- A. If 1, 2, 3, only are correct
- B. If 1 and 3 only are correct
- C. If 2 and 4 only are correct
- D. If 4 only is correct

17. Which one of the following is **not** a property of diamond?
Diamond.
- A. Is very hard
 - B. Is a good conductor of heat
 - C. Burns in oxygen to produce carbon dioxide
 - D. It is colorless and transparent
18. Which of the following substance(s) is /are formed when sodium hydrogen carbonate is reacted with dilute hydrochloric acid
- 1. Hydrogen
 - 2. Sodium chloride
 - 3. Sodium hydroxide
 - 4. Carbon dioxide
19. Which of the following is/are true about diamond and graphite
- 1. Their atoms have the same mass number
 - 2. Both conduct electricity
 - 3. Both burn in excess air to produce carbon dioxide
 - 4. Both have layer lattice
20. Which of the following has/have a giant molecular structure?
- 1. Sulphur
 - 2. Graphite
 - 3. Phosphorus
 - 4. diamond
21. Which of the following is/are true about diamond and graphite?
- 1. They have the same atomic mass
 - 2. They are isotopes
 - 3. They are allotropes
 - 4. They show similar physical properties

22. Which of the following properties make carbon dioxide useful in fire extinguishers?
1. It is denser than air
 2. It is lighter than air
 3. It is non flammable
 4. It is inert gas
23. Carbon is similar to sulphur in that both
1. Are non metallic solid
 2. Exist in allotropic form
 3. Form covalent compound
 4. Form neutral oxide

Section B

Your answers should be precise as possible

24. (a) Soot is a form of carbon
- (i) Write an equation for complete combustion of soot in oxygen (1mark)
 - (ii) Calculate the volume of gas produced at room temperature, when 0.6g of soot is burnt in excess oxygen. (2marks)
(C= 12, 1 mole of a gas occupies 24.0dm³ at room temperature)
 - (iii) Deduce the volume of the gas that would be produced at room temperature if the same mass of graphite was burnt in excess oxygen (½ mark)
 - (iv) Give a reason for your answer in (a) (iii) (1mark)
- (b) State 1 industrial use of graphite (½ mark)
25. (a) (i) Name two allotropes of carbon other than charcoal (1mark)
- (ii) State one use of each of the allotropes you have named in (a)(i) above. (2marks)
- (b) (i) State the condition under which sulphuric acid can react with sugar C₁₂H₂₂O₁₁ to form carbon. (1mark)
- (ii) Write equation for the reaction. (1mark)
26. (a) Describe briefly the structure of graphite (3 ½ mark)
- (b) State two properties in which graphite differ from diamond (2marks)
- (c) Graphite was heated in excess air and the gas given off passed through aqueous sodium hydroxide for a long time.
- (i) State what was observed (1mark)
 - (ii) Write equation(s) for the reaction(s) that took place (3marks)
- (d) Carbon monoxide reacts with Iron (III) oxide according to equation (3 ½ marks)
- $$\text{Fe}_2\text{O}_3(\text{s}) + 3\text{CO}(\text{g}) \longrightarrow 3\text{Fe}(\text{s}) + 3\text{CO}_2(\text{s})$$
- If excess carbon monoxide was passed over 3.5g of hot iron (III) oxide, calculate the volume of carbon dioxide produced at s.t.p.? (Fe = 56, O =16, C =12)
27. (a) Sodium carbonate is more soluble in water than sodium hydrogen carbonate.

- Briefly, describe how a dry sample of sodium hydrogen carbonate can be obtained from solution containing both salt.
- (b) Write equations for the reaction that would take place if
- (i) Dilute hydrochloric acid is added to sodium hydrogen carbonates (1 ½ marks)
 - (ii) sodium hydrogen carbonate is strongly heated (1 ½ marks)
- (c) State what would be observed and write equation for the reaction that would take place if magnesium sulphate solution to a solution containing
- (i) Carbonate ions
 - (ii) Hydrogen carbonate ion
- (d) 6.4g of an impure sample of anhydrous sodium carbonate was dissolved in water and the solution made to 500cm³. 25cm³ of this solution required 24.0cm³ of 0.1M hydrochloric acid solution complete reaction.
Calculate
- (i) Number of the acid that reacted. (1 ½ mark)
 - (ii) Number of moles of carbonate that reacted (1mark)
 - (iii) Percentage purity.

Marking guide

1	D	6	D	11.	B	16	A	21	B
2	D	7	D	12	B	17	B	22	B
3	D	8	D	13	B	18	C	23	A
4	B	9	B	14	C	19	B	24	
5	D	10	C	15	D	20	D	25	

24. (a) (i) $C(s) + O_2(g) \rightarrow CO_2(g)$
 (ii) 12g produce 24 dm³ of CO_2
 $\Rightarrow 0.6g \text{ produce } \frac{24 \times 0.6}{12} = 1.2 dm^3$
 (iii) 1.2 dm³
 (iv) Because soot and graphite are the same element
 (b) Graphite is used in the manufacture of lubricants and lead pencils
25. (a) (i) Diamond and graphite
 (ii) Diamond for making ornaments, glass cutter, drillers
 Graphite for making lead pencil, lubricant
 (b) (i) Sulphuric acid is concentrated
 (ii) $C_{12}H_{22}O_{11} \xrightarrow{\text{Conc. } H_2SO_4} 12C(s) + 11H_2O(l)$
26. (a) In graphite each carbon is bonded to 3 carbon atoms to form a layer of hexagonal rings. Each layer is bonded to one another by weak bonds, making graphite slippery.
 (b) - Graphite conducts electricity while diamond does not
 - Graphite is soft while diamond is very hard
 (c) (i) A colorless solution first and finally white precipitate
 (ii) $2NaOH(aq) + CO_2(g) \longrightarrow Na_2CO_3(aq) + H_2O(l)$
 Then
 $Na_2CO_3(aq) + CO_2(g) + H_2O(l) \longrightarrow 2NaHCO_3(s)$
 (d) Rfm of $Fe_2O_3 = 26 \times 2 + 16 \times 3 = 158$
 158g of Fe_2O_3 produce $(3 \times 22.4) dm^3$ of carbon dioxide
 $\Rightarrow 3.5 \text{ g of } Fe_2O_3 \text{ produce } \frac{3 \times 22.4 \times 3.5}{158} = 1.5 dm^3$
27. (a) By recrystallization
 (b) (i) $NaHCO_3(s) + HCl(aq) \longrightarrow NaCl(aq) + CO_2(g) + H_2O(l)$
 (ii) $2NaHCO_3 \xrightarrow{\text{heat}} Na_2CO_3(s) + CO_2(g) + H_2O(l)$
 (c) (i) White precipitate
 (ii) No observable change
 (d) (i) Moles of acid = $\frac{24 \times 0.1}{1000} = 0.0024 \text{ moles}$
 (ii) $Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$
 2moles of HCl react with 1 mole of Na_2CO_3
 $\therefore 0.0024 \text{ mole of HCl react with } 0.0012 \text{ moles of } Na_2CO_3$