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CHEMISTRY

Paper 2 (Theory) - All Variants

(Syllabus 5070)

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period	2013 to 2025
contents	June & November, Paper 2 (All Variants), Worked Solutions
form	Topic By Topic
compiled for	O Levels

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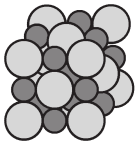
June **2024** Paper 2 (All Variants)
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November **2025** Paper 2 (All Variants)

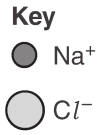
TOPIC 3.2

Ionic, Covalent & Metallic Bonding

1. ***[June 2013/P22/Q10 a]***

Solid sodium chloride and magnesium oxide have the same structure and bonding.
This is the structure of sodium chloride.





The table shows the melting point of these two compounds.

compound	melting point / °C
magnesium oxide	2852
sodium chloride	801

(i) What are the formulae for a magnesium ion and an oxide ion?

..... [1]

(ii) Suggest why magnesium oxide has a much higher melting point than sodium chloride.

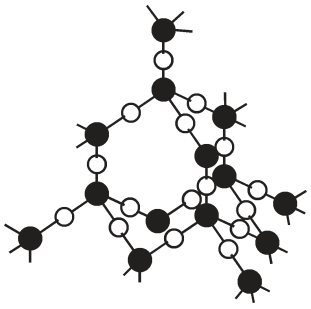
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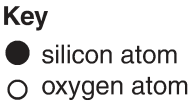
..... [1]

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2. ***[Nov 2013/P22/Q3 e]***

Silicon(IV) chloride reacts with water to form silicon(IV) oxide.
Part of the structure of silicon(IV) oxide is shown below.





Explain, in terms of structure and bonding, why silicon(IV) oxide has a very high melting point.

.....

.....

..... [2]

---

3. ***[June 2014/P21/Q10 d]***

Describe, with the aid of a labelled diagram, the structure of a metal and use it to explain why francium is a good conductor of electricity.

.....

.....

..... [3]

---

4. ***[June 2014/P22/Q10 c,d]***

(a) Astatine reacts with magnesium to form magnesium astatide, $MgAt_2$, which contains Mg^{2+} and At^- ions.

(i) Describe how a magnesium ion and an astatide ion are formed from a magnesium atom and an astatine atom.

.....

.....

..... [2]

(ii) Predict **two** physical properties of magnesium astatide.

1. .....

2. ..... [2]

(b) (i) Bromine reacts with aqueous magnesium astatide. Construct the ionic equation for this reaction.

..... [1]

(ii) Explain why astatine does not react with aqueous magnesium iodide.

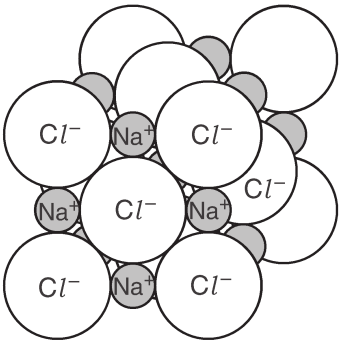
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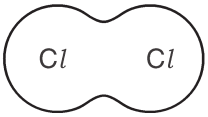
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5. ***[Nov 2014/P22/Q6 a,b,c]***

The structures of sodium chloride and chlorine are shown below.



sodium chloride



chlorine

(a) The melting point of sodium chloride is 801 °C.
The melting point of chlorine is –101 °C.

Explain, in terms of structure and bonding, the difference between the melting points of these two substances.

.....

.....

.....

.....

.....

..... [4]

(b) Explain why molten sodium chloride conducts electricity but solid sodium chloride does not.

.....

.....

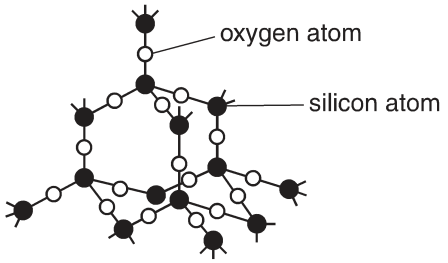
..... [1]

(c) Draw a 'dot-and-cross' diagram for sodium chloride, showing all the electron shells.

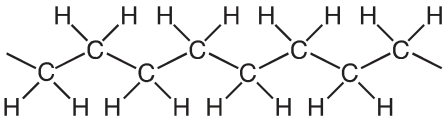
[2]

6. ***[Nov 2014/P21/Q6 a]***

Parts of the structures of silicon dioxide and poly(ethene) are shown below.



silicon dioxide



poly(ethene)

The melting point of silicon dioxide is 1610 °C.

Poly(ethene) starts to melt at 130 °C.

Explain, in terms of structure and bonding, the difference between the melting points of these two substances.

.....

.....

.....

.....

.....

..... [4]

---

7. ***[June 2015/P21/Q4 c,d,e,f,g]***

(a) Sulfur forms simple molecules which have a relative molecular mass of 256.

Suggest the formula of a sulfur molecule.

.....

..... [1]

(b) Sulfur has a low melting point and does not conduct electricity.

(i) Explain why sulfur has a low melting point.

.....

..... [1]

(ii) Explain why sulfur does not conduct electricity.

.....

..... [1]

(c) Sulfur reacts with potassium to form potassium sulfide.

Write the formula and the electronic configuration of the positive ion and of the negative ion in potassium sulfide.

positive ion

formula ..... electronic configuration .....

negative ion

formula ..... electronic configuration .....

[2]

(d) Sulfur reacts with hydrogen to form hydrogen sulfide, H_2S.

Draw the 'dot-and-cross' diagram to show the bonding in a molecule of hydrogen sulfide.

Only draw the outer shell electrons.

[2]

(e) Hydrogen sulfide reacts with sulfur dioxide to form sulfur and water.

Write the equation for this reaction.

..... [1]

---

8. ***[June 2015/P21/Q7 e(i)]***

Molybdenum has a melting point of 2623 °C.

Describe metallic bonding, with the aid of a labelled diagram.

.....

.....

..... [2]

---

9. ***[June 2015/P22/Q3 b,c]***

(a) Phosphorus forms simple molecules which have a relative molecular mass of 124.
Suggest the formula of a phosphorus molecule.

..... [1]

(b) Phosphorus has a low melting point and does not conduct electricity.

(i) Explain why phosphorus has a low melting point.

.....

..... [1]

(ii) Explain why phosphorus does not conduct electricity.

.....

..... [1]

---

10. ***[June 2015/P22/Q7 e,f]***

(a) Titanium(IV) chloride is a liquid with a low boiling point of 126 °C.
Suggest the structure and bonding of titanium(IV) chloride.

.....

..... [2]

(b) Explain how titanium metal conducts electricity.

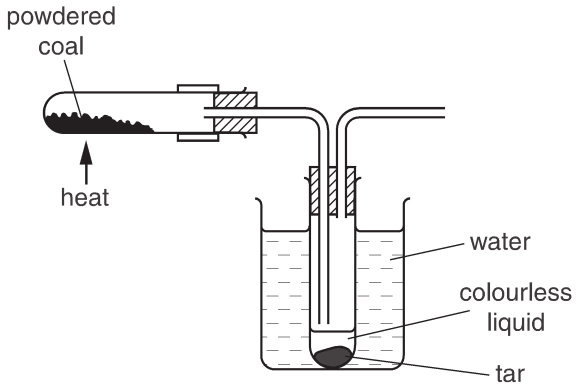
.....

..... [1]

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11. ***[Nov 2015/P21/Q2 a]***

Coal is a mixture of carbon compounds with a small amount of sulfur.
A sample of coal is heated in the absence of air using the apparatus shown.



The distillate is a mixture of a colourless liquid and tar.
The colourless liquid contains ammonia, NH_3.

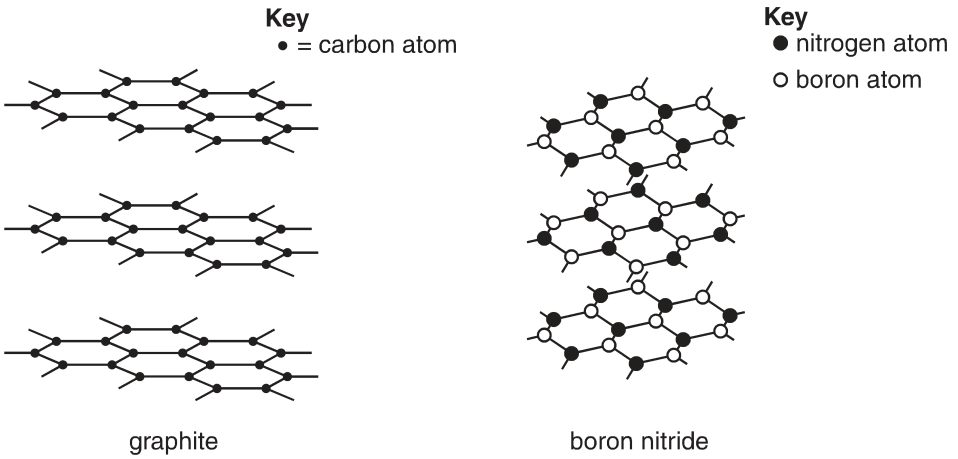
Draw a 'dot-and-cross' diagram for ammonia.
Show only the outer shell electrons.

[2]

---

12. ***[Nov 2015/P21/Q7 a,b,c]***

The structures of graphite and boron nitride are shown below.



graphite boron nitride

(a) Like graphite, boron nitride feels slippery to the touch.
Explain, in terms of structure and bonding, why boron nitride feels slippery to the touch.

.....

.....

..... [2]

(b) An isotope of boron is represented by the symbol $^{11}_{5}B$.
Deduce the number of protons and neutrons in this isotope of boron.

number of protons .....

number of neutrons ..... [1]

(c) Explain why graphite has a high melting point.

.....

.....

..... [2]

ANSWERS

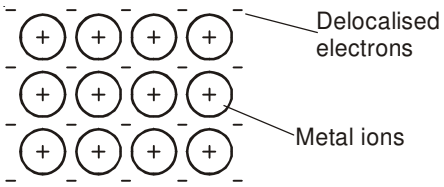
Topic - 3.2

1. **(i)** Mg^{2+} and O^{2-}

(ii) Magnesium oxide has strong electrostatic forces of attraction between the ions due to a higher charge on them as compared to sodium chloride.

2. Many strong covalent bonds form a giant lattice. High temperature (or a lot of energy) needed to break these strong bonds.

3.



It has delocalised (free) electrons, thus good conductor of electricity.

4. **(a)** **(i)** A magnesium atom loses two electrons to form a magnesium ion. Each astatine atom gains one electron to form an astatide ion.

(ii) *Any two from:*

- High melting point.
- Does not conduct electricity as a solid.
- Conducts electricity when molten.

(b) **(i)** $Br_2 + 2At^- \rightarrow 2Br^- + At_2$

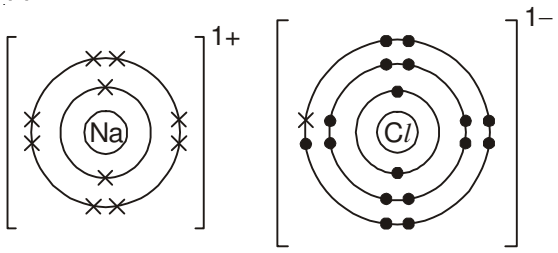
(ii) Astatine is less reactive than iodine. (or, Iodide ions are more difficult to oxidise than astatide ions).

5. **(a)** Sodium Chloride has a giant ionic structure with strong forces of attraction between them. These strong ionic bonds require a lot of energy to break.

Chlorine has a simple covalent structure with weak intermolecular forces. The bonds require a small amount of energy to break.

(b) In molten sodium chloride ions can move but ions cannot move in solids.

(c)



6. Silicon dioxide forms a giant covalent structure with strong bonds linked in 3-dimensions. These bonds require a high temperature to break.

Poly (ethene) on the other hand has weak forces between the molecules and they require only a small amount of energy to break the weak bonds.

7. **(a)** S_8

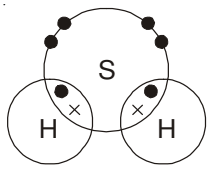
(b) **(i)** It has weak intermolecular forces (or weak attraction between its molecules).

(ii) Sulfur has no delocalized or free electrons to conduct electricity.

(c) K^+ and 2,8,8

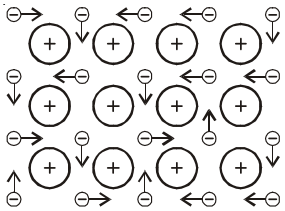
S^{2-} and 2,8,8

(d)



(e) $2H_2S + SO_2 \rightarrow 3S + 2H_2O$

8.



The metal atoms lose their valence electrons and become positively charged. These valence electrons forms a sea of electrons and are free to move between the positive ions. Strong metallic bonds are formed as a result of attraction between these ions and electrons.

9. **(a)** P_4.

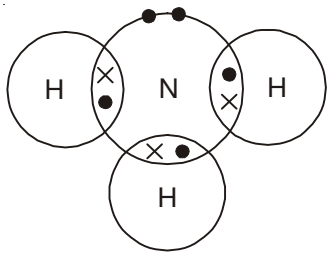
(b) **(i)** Weak intermolecular forces / weak attraction between molecules.

(ii) Phosphorus has no delocalised (or free) electrons.

10. **(a)** Titanium (IV) Chloride has a simple molecular structure with covalent bonding.

(b) Titanium metal has delocalized electrons which are free to move and conduct electricity.

11.



12. **(a)** Weak van der Waals' forces between layers. Layers easily slide over each other.

(b) Protons: 5. Neutrons: 6.

(c) Graphite forms a giant lattice structure where a lot of energy (or high temperature) is needed to break the strong bonds.

13. **(a)** Atoms arranged tetrahedrally.

Alternatively: tetrahedral structure / bent hexagonal structure / four atoms round carbon and four atoms round silicon / both giant structures / both lattices / both macromolecules.

(b) Silicon dioxide has a giant macromolecular structure, consisting of strong covalent bonds that require a lot of energy to be broken. This causes silicon dioxide to have a high melting point.

(c) SiO_3^{2-}.

(d) In diamond all four valence electrons are involved in bonding. Therefore, there are no delocalized electrons to conduct electricity.

14. In solid sodium chloride there are no free ions to conduct electricity as all the ions are held together in fixed positions. However, in molten state the ions are free to move and therefore can conduct electricity.

15. **(i)** *Any two from:*

- High melting point.
- Does not conduct electricity as a solid.
- Soluble in water.
- Conducts electricity as a molten liquid.

(ii) Upon reaction with sulfur, the magnesium atom loses 2 electrons and form a Magnesium ion while sulfur gains these 2 electrons to form a sulfide ion.

16. **(i)** *Any two from:*

- High melting point.
- Does not conduct electricity as a solid.
- Soluble in water.
- Conducts electricity as a molten liquid.

(ii) Magnesium atom loses 2 electrons and fluorine molecule gains 2 electrons. Each fluorine atom gains one e^- leaving +2 charge on magnesium and –1 charge on fluorine.

17. **(i)** Upon reaction with Chlorine, the potassium atom loses an electron to form a potassium ion while chlorine gains this electron to form chloride ion. Both ions have 8 outer shell electrons after the reaction.

(ii)
- High melting point / High boiling point.
- Dissolves in water.
- Does not conduct electricity when solid.
- Conducts electricity when molten.

18. Calcium chloride has ionic bonds with strong forces of attraction between the positive ions and negative ions. These bonds require high temperature to break.

19. Sodium ion: 2, 8 Oxide ion: 2, 8

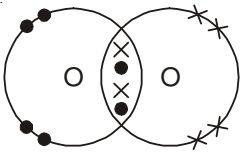
20. **(a)** *Arrangement:* Ordered / lattice / regular / layers / uniformly arranged.

Type of attractive force: Electrostatic.

(b) Solid: Ions cannot move.

Aqueous: Ions can move.

(c)



21. (a) (i)
- Giant molecular structure / many covalent bonds.
- Takes a lot of energy (high temperature) to break the bonds.

(ii) Diamond has a much higher melting point than tin and does not conduct electricity. Diamond has a giant covalent structure whereas tin has a metallic structure.

(iii) Oxide which reacts with acids or bases.

(b)
- Simple molecular structure.
- Covalent bonding

22. (a) *Arrangement:* Ordered / lattice / regular / layers / uniformly arranged.

Type of attractive forces: Electrostatic.

(b) When magnesium chloride is a crystal solid, the ions are held together in a fixed position, while in aqueous state, these ions are free to move which enables the electricity to be conducted.

(c) Magnesium ion: 2,8

Chloride ion: 2,8,8

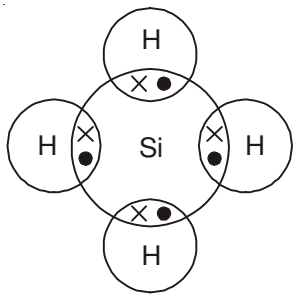
23. (a) (i) Magnesium has a giant structure where the positive ions are bonded strongly to one another. Sulfur, on the other hand, has a simple structure with weak forces between the molecules.

(ii) Magnesium has delocalised electrons which are free to move from one place to another. In sulfur, the electrons are not delocalised and their immobility prevents the conduction of electricity.

(b) Silicon has a giant covalent structure and a lot of energy (or high temperature) is required to break these bonds.

24. (a) *Any two from:*
- High melting point / high boiling point.
- Poor conductor of electricity.
- Does not dissolve in water.
- Very hard.

(b) (i)



(ii) Silane has a simple (molecular or covalent) structure with weak intermolecular forces. It requires less energy to break attraction between the molecules.

25. (a) *Any two from:*
- Low melting point / low boiling point.
- Poor conductor of electricity
- Poor conductor of heat.
- Does not dissolve in water.

(b)
- It has a giant ionic structure.
- Strong attraction between ions
- Difficult to break attraction between ions.
- Lot of energy needed to overcome strong attractive forces between ions.

26. (a) (i) Liquid.

–200 °C is between the boiling and melting points. This temperature is higher than the melting point but lower than the boiling point.

(ii) Any value between 50 °C and 600 °C (inclusive).

(b) Nitrogen is a simple covalent molecule and has weak forces between molecules.

Bismuth has metallic bonding / metallic structure.

(c) $2Sb + 3Cl_2 \rightarrow 2SbCl_3$

27. In solid ammonium carbonate all the ions are held together in fixed positions. However, in aqueous state the ions are free to move and therefore can conduct electricity.

Topic 7 Chemical Reactions

TOPIC 7.1

Rate of Reaction

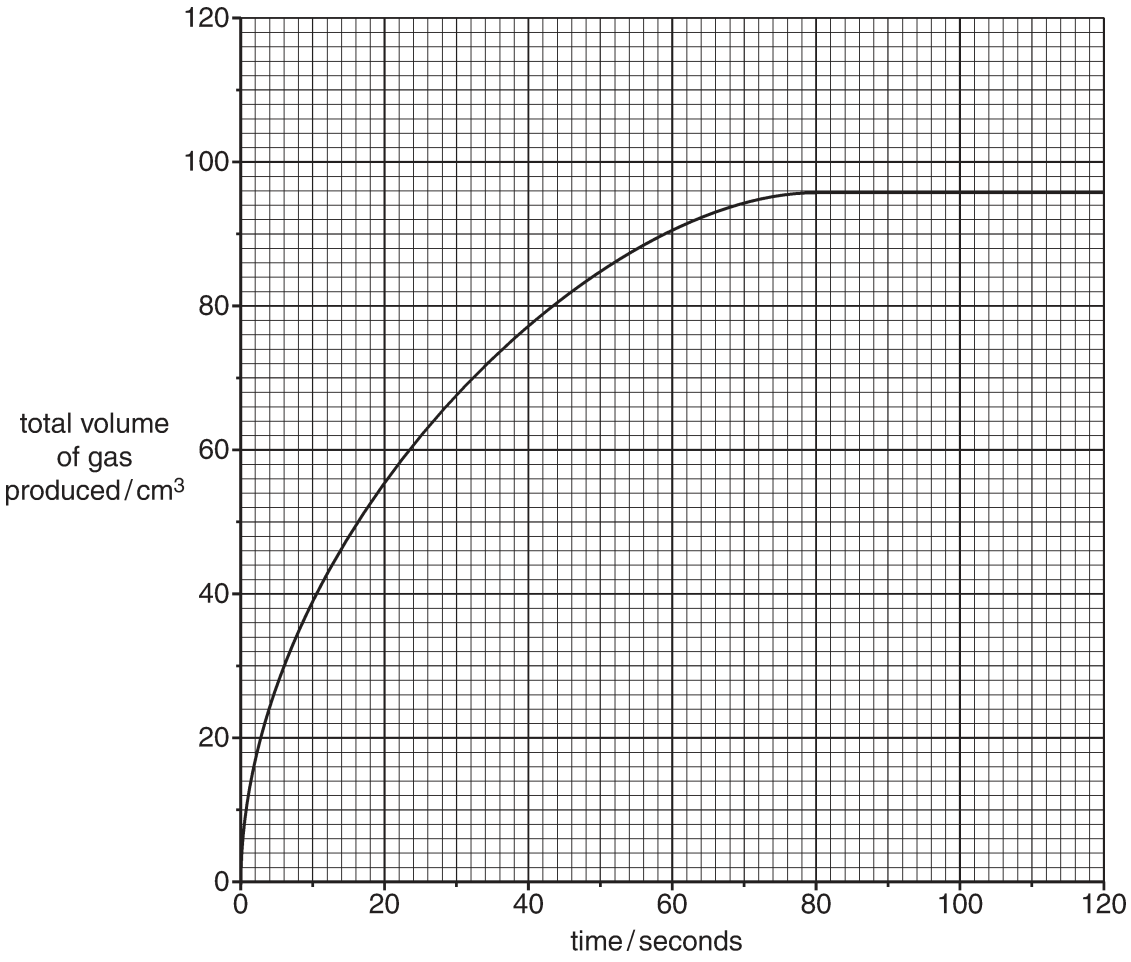
1. ***[June 2013/P22/Q7]***

An antacid tablet contains a mixture of magnesium hydroxide, $Mg(OH)_2$, and calcium carbonate, $CaCO_3$.

Stomach acid contains dilute hydrochloric acid.

A student adds a 0.500 g antacid tablet to 50.0 cm^3 of 1.00 mol/dm^3 hydrochloric acid, HC*l*. The acid is in excess.

The graph shows how the total volume of gas produced at r.t.p. changes with time.



(a) Describe, with the aid of a labelled diagram, the apparatus needed to collect this data.

[2]

(b) (i) Write equations for the reactions of HC*l* with $Mg(OH)_2$ and also with $CaCO_3$.

$Mg(OH)_2$

.....

$CaCO_3$

..... [2]

(ii) Calculate the amount, in moles, of carbon dioxide formed at r.t.p. once the reaction had stopped.

amount in moles = ... [2]

(iii) Calculate the mass of $CaCO_3$ in the tablet.

mass of $CaCO_3$ = ... g [2]

(c) The student repeats the experiment. This time she uses a 0.500 g antacid tablet and 50.0 cm^3 of **2.00 mol/dm^3** HC*l* instead of 50.0 cm^3 of 1.00 mol/dm^3 HC*l*.

Describe and explain what will happen to the rate of reaction.

.....

.....

.....

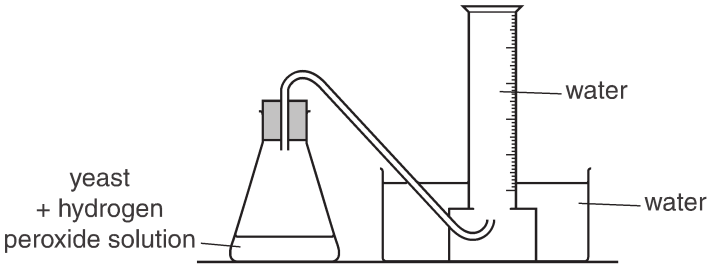
..... [2]

2. ***[Nov 2013/P21/Q5 b,c,d]***

(a) The enzyme catalase is present in yeast. The enzyme catalyses the decomposition of aqueous hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

The apparatus below is used to monitor this reaction.



What measurements should be taken in order to monitor the rate of this reaction?

.....

..... [2]

(b) Describe and explain the effect of increasing the concentration of hydrogen peroxide on the rate of this reaction.

.....

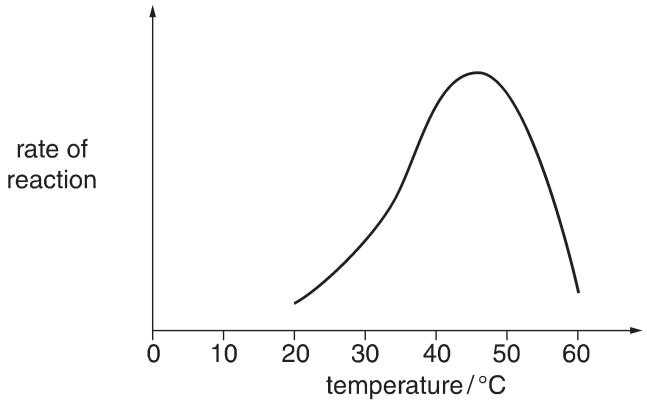
.....

.....

.....

..... [3]

(c) The graph below shows how the rate of decomposition of hydrogen peroxide, catalysed by yeast, varies with temperature. All other conditions are kept constant.



Suggest why the rate of reaction decreases rapidly from 45 °C to 60 °C.

..... [1]

3. ***[Nov 2013/P22/Q5 a,b]***

A student reacts magnesium ribbon with excess hydrochloric acid.

She follows the course of the reaction by measuring the volume of gas produced against time.

(a) Write the equation for the reaction of magnesium with hydrochloric acid.

..... [1]

(b) (i) On the axes below draw a sketch graph to show how the volume of gas produced during the reaction varies with time and label this line 'A'.

Label the axes with the appropriate units.



[2]

(ii) The student then carries out the experiment at a **lower** temperature. All the other conditions remain the same.

On the axes above draw another line to show how the volume of gas produced varies with time and label this line 'B'. [1]

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4. ***[June 2014/P21/Q3]***

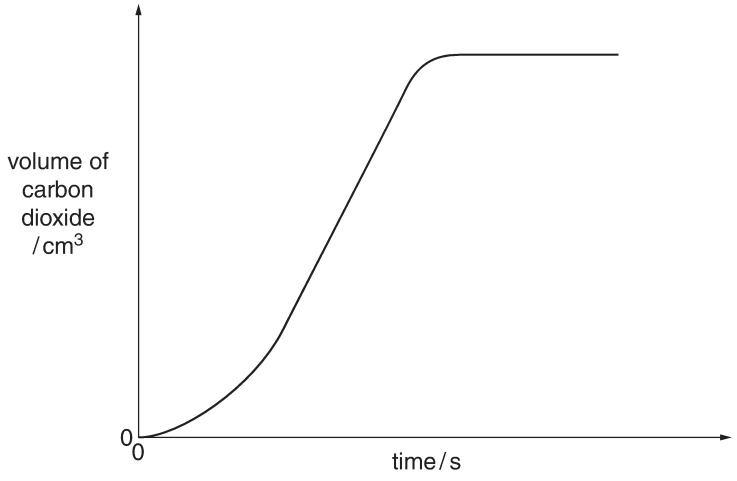
Zinc carbonate thermally decomposes to form zinc oxide and carbon dioxide.

$$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$$

In an experiment, a sample of zinc carbonate is heated in a test-tube using a Bunsen burner.

The total volume of carbon dioxide formed is measured every 10 seconds.

The results are plotted on the graph below.



(a) Suggest why the volume of carbon dioxide does not increase by very much when the zinc carbonate is first heated.

.....

..... [1]

(b) How is the graph used to find out when the decomposition has finished?

..... [1]

(c) The same mass of zinc carbonate is heated using a **hotter** Bunsen flame.

On the axes above, draw the graph you would expect from the results of this experiment.

Explain your answer.

.....

.....

.....

..... [4]

(d) The experiment is repeated with different metal carbonates.

The Bunsen burner flame is not altered and the same number of moles of metal carbonate is used for each experiment.

The table shows the time taken for complete decomposition.

metal carbonate	time for decomposition to finish / s
$CaCO_3$	360
$FeCO_3$	60
$ZnCO_3$	70

Predict and explain the time it would take magnesium carbonate and lead carbonate to decompose.

magnesium carbonate ..... s

lead carbonate ..... s

explanation .....

.....

.....

..... [2]

5. ***[June 2014/P21/Q9 d]***

When carbon dioxide reacts with hydrogen in a sealed container, an equilibrium mixture is obtained.

$$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g) \qquad \Delta H = -205 \text{ kJ/mol}$$

This reaction is exothermic.

The experiment with 220 g of carbon dioxide and an excess of hydrogen is repeated but this time a catalyst is added.

(i) State what happens, if anything, to the position of equilibrium compared with the noncatalysed reaction.

.....

..... [1]

(ii) Describe and explain what happens to the rate of reaction compared with the noncatalysed reaction.

.....

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.....

..... [2]

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6. ***[Nov 2014/P21/Q5 b]***

A student added excess calcium carbonate to 50 cm^3 of 0.10 mol/dm^3 hydrochloric acid.

(i) Construct an equation for the reaction of calcium carbonate with hydrochloric acid.

..... [1]

(ii) The volume of gas produced in the first 2 minutes is 24 cm^3.

Calculate the average rate of reaction over the first 2 minutes, in cm^3/s.

reaction rate = ... cm^3/s [1]

(iii) The student repeats the experiment using 50 cm^3 of 0.10 mol/dm^3 ethanoic acid.

Use the kinetic particle theory to explain why the rate of reaction is slower with ethanoic acid than with hydrochloric acid.

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..... [3]

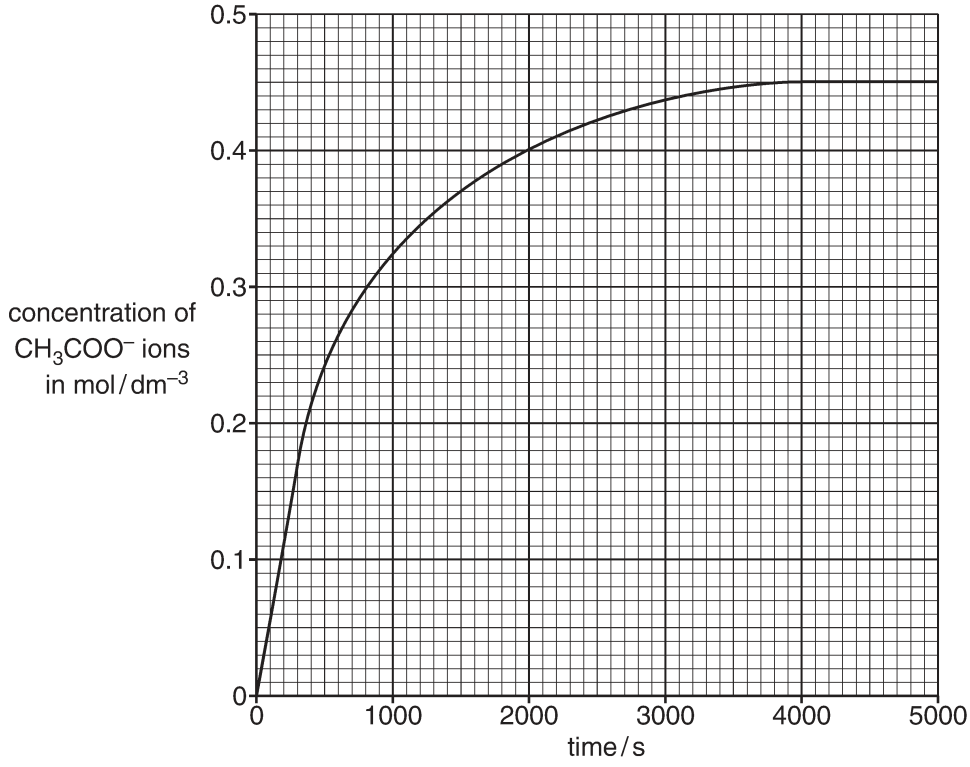
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7. ***[Nov 2014/P22/Q8 a]***

The ester, ethyl ethanoate, reacts with hydroxide ions to form ethanoate ions and ethanol.

$$\underset{\text{ethyl ethanoate}}{CH_3COOC_2H_5} + OH^- \rightarrow \underset{\text{ethanoate ions}}{CH_3COO^-} + C_2H_5OH$$

The graph shows how the concentration of ethanoate ions, CH_3COO^-, changes as the reaction proceeds.



(i) Use the information in the graph to deduce the mass of ethanoate ions in 200 cm^3 of solution when the reaction is complete.

mass = ... g [2]

(ii) Use the information in the graph to calculate the average rate of reaction, in mol/dm^3/s, during the first 300 seconds.

average rate of reaction ..... mol/dm^3/s [1]

(iii) Describe and explain, using the kinetic particle theory, the change in the rate of reaction with time.

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..... [3]

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8. ***[June 2015/P22/Q8 b]***

The equation shows the reaction to make propenenitrile.

$$2C_3H_6(g) + 2NH_3(g) + 3O_2(g) \rightarrow 2C_3H_3N(g) + 6H_2O(g)$$

Describe and explain what happens to the rate of this reaction if the temperature is increased.

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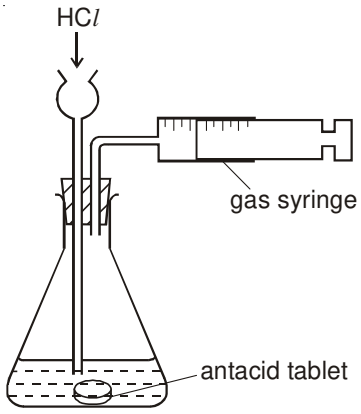
.....

..... [2]

ANSWERS

Topic - 7.1

1. (a)



Hydrochloric acid is added in excess through the dropping funnel, and the stopwatch is started. The volume of gas produced is noted in the gas syringe with respect to time, until the gas syringe shows a constant reading .

(b) (i) $Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$

$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

(ii) Volume of CO_2 from graph $= 96\ cm^3$

$$\text{Moles of } CO_2 = \frac{96}{1000} \times \frac{1}{24} = 0.004$$

(iii) M_r of $CaCO_3 = 100$

Mass of $CaCO_3 = 100 \times 0.004 = 0.4\ g$

(c) With an increase in concentration of the acid, the particles come closer to one another leading to more frequent collisions. This increases the rate of reaction.

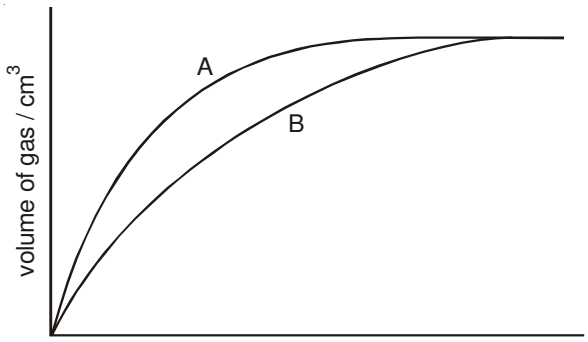
2. (a) Measure the volume of oxygen at various times.

(b) More number of particles of H_2O_2, particles closer together, more successful collisions thus the rate of reaction increases.

(c) Yeast dies at high temperatures.

3. (a) $Mg + 2HCl \rightarrow MgCl_2 + H_2$

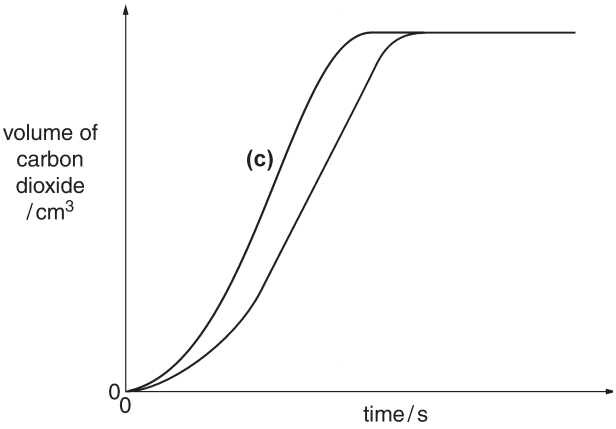
(b) (i) & (ii)



4. (a) Initially zinc carbonate is cold so a low speed of reaction.

(b) First time when the line is horizontal.

(c)



Reaction is faster as particles have more energy. There are more successful collisions between particles.

(d) $MgCO_3$: Any time between 70 s and 360 s

$PbCO_3$: Any time Less than 60 s

The time taken for the decomposition to take place depends on the position of the metal in the reactivity. The more reactive metals takes longer time.

5. **(i)** No effect / does not change.

(ii) Speed of reaction increases.
Activation energy is lowered / reaction follows a different pathway.

6. **(i)** $CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$

(ii) Average rate of reaction

$$= \frac{24}{2 \times 60} = 0.2 \text{ cm}^3/\text{s}$$

(iii) Ethanoic acid, being a weak acid, dissociates only partially while hydrochloric acid dissociates fully. With a low concentration of H^+ ions in ethanoic acid, there is a lower frequency of collisions with $CaCO_3$ which is why the reaction occur slowly.

7. **(i)** M_r of ethanoate ions $= 59$

From graph, concentration of ethanoate ions $= 0.45 \text{ mol/dm}^3$

$$\therefore \text{ moles of ethanoate ions} = 0.45 \times \frac{200}{1000}$$
$$= 0.09 \text{ moles}$$

Mass of ethanoate $= 0.09 \times 59 = 5.31$ g

(ii) Average rate of reaction

$$= \frac{0.17}{300} \approx 5.67 \times 10^{-4} \text{ mol/dm}^3/\text{s}$$

(iii) As the reaction proceeds, the concentration of H^+ ions for the reaction decreases as the reactants gets used up. This leads to a reduced collision frequency and a decrease in rate of reaction with time.

8. When gases are heated the particles gain more kinetic energy and move faster. Their increased speed increases the chance of effective collisions between reactant molecules and thereby increasing the rate of reaction.

9. When a Magnesium powder is used, the surface area for the reaction to occur increases which leads to more frequent collisions between the H^+ ions and Magnesium.

10. **(a)** Peroxodisulfate ions: Increases the rate of reaction. Doubling concentration doubles the rate.

Iodide ions: Increases the rate of reaction. Doubling concentration doubles the rate.

(b) Catalysts increases the rate of reaction by lowering the activation energy.

11. **(a)** *Propane:* Increases the rate of reaction with an increase in concentration.

Iodine: No effect on rate.

Hydrochloric acid: Increases the rate of reaction with an increase in concentration.

(b) With an increased temperature, more number of particles have energy greater than the activation energy of the reaction which leads to more successful collisions and an increase in the rate.

12. An enzyme, like a catalyst, provides a different pathway for a reaction with a lowered activation energy. This increases the number of particles with energy greater than the activation energy of the reaction. Therefore more successful collisions occur resulting in a faster reaction.

13. **(a)** As the reaction proceeds, the rate decreases which is denoted by a decreasing gradient of the graph.

(b) As the concentration of cyclopropane increases, the particles come closer together which leads to more number of collisions per second. This increases the rate of reaction.

(c) As the temperature decreases, the particles move more slowly. The number of effective collisions decreases as only a few particles will have energy equal to or greater than the activation energy. This decreases the rate of reaction.

14. **(i)** As we double the concentration of N_2O_5, the rate of reaction also doubles.

(ii) As the concentration of N_2O_5 increases, the particles in a given volume come closer together leading to a higher frequency of collision and thus a higher rate of reaction.

(iii) When temperature increases, the particles have greater kinetic energy. More number of particles now have energy greater than the activation energy of the reaction which leads to more successful collisions and an increased rate of reaction.

15. **(i)** When pressure increases, the particles come closer and now there are more particles in the same volume. This leads to a higher frequency of collisions and thus the rate of reaction increases.

(ii) A catalyst, provides an alternative reaction pathway with a lowered activation energy. This increases the number of particles with energy greater than the activation energy of the reaction which leads to more successful collisions and an increased rate of reaction.

16. Catalysts conserves energy resources by lowering the temperature or pressure needed for a reaction to occur. This also decreases the heating or fuel costs in industries.

17. **(a)** As the concentration decreases, the particles in a given volume get further apart. The frequency of collision also decreases. Thus the rate of reaction decreases

(b) When Large pieces are used, the exposed surface area for the reaction to occur decreases. Thus the rate of reaction decreases.

18. **(a)** With increase in concentration, more particles are confined per unit volume. As a result, the frequency of collision between particles increases, thus increasing the rate of the reaction.

(b) When the temperature is decreased, particles possess less kinetic energy, which results into fewer particles having enough energy to overcome activation energy. As a result, rate of reaction decreases.

19. **(a)** Titration method
Use aqueous sodium hydroxide of known concentration.
Add indicator to the acid in the titration flask.
Use a known volume of acid.
Record volume of alkali added when indicator changes colour.

(b) **(i)** 1.38 mol/dm^3.

(ii) **A**. Gradient of graph is greatest at this point.

(c) When the temperature is decreased, particles possess less kinetic energy, which results into fewer particles having energy above (or equal to) the activation energy. The frequency of collision decreases. As a result, rate of reaction decreases.

(d) Turns it red.

(e) Lead chloride (or Silver chloride).

20. **(a)** Progress of the reaction can also be followed by measuring the volume of carbon dioxide at regular time intervals.

(b) By using smaller pieces of calcium carbonate, the surface area available for the acid to react increases. This would result in an increase in the frequency of successful collisions between acid and exposed calcium carbonate, thus increasing the rate of reaction.

(c) When the temperature is increased the particles in the reaction move faster. A larger number of particles will now possess kinetic energy higher than the activation energy of the reaction, resulting in more collisions per second. Thus the rate of reaction is faster at a higher temperature.

21. The particles have more energy. More number of particles now have energy greater than the activation energy of the reaction which leads to more successful collisions.

22. When using a Magnesium ribbon instead of powder, the rate of reaction decreases because now fewer magnesium particles are exposed on the surface which leads to less frequent collisions between particles.

23. As the concentration of NH_4NO_2 is decreased fewer particles per unit volume are available for the reaction. This decreases the collision frequency, eventually decreasing the rate of reaction.

24. **(a)** Moles of $NaNO_2 = \frac{20}{1000} \times 0.150 = 0.003$

Molar ratio $NaNO_2 : N_2 = 1:1$

$\therefore$ Moles of N_2 formed $= 0.003$

Volume of N_2 formed $= 0.003 \times 24$

$= 0.072$ dm^3

(b)

