Answers

Chapter 1

Level 1

1. **A**
   Burette is a very accurate instrument that can measure volumes of solutions up to 2 decimal places.
2. **A**
   A conical flask is usually used in a distillation set-up, not a beaker. Boiling chips ensure that heat is evenly distributed in the distillation flask. A condenser is required to condense the liquid distillate. A thermometer is required to measure the boiling point of the distillate.
3. **C**
   If a substance melts at a fixed temperature, it would indicate that the substance is pure. If the substance is impure, it would melt over a range of temperatures.
4. **A**
   Downward delivery is used to collect gases that are denser than air while upward delivery is used to collect gases that are less dense than air. Displacement of water is used for gases that are insoluble in water.
5. **A**
   The inner surface of a filter funnel can be used as a surface to deposit gases into solids. Only solid ammonium chloride and iodine can sublime into gases and hence their gases can be deposited into solids on the inner surface of the filter funnel.

Level 2

6. **C**
   Sulfur dioxide is denser than air and hence can be collected by downward delivery. Hydrogen is less dense than air and insoluble in water. Hence, it can be collected by upward delivery or displacement of water.
7. **D**
   Solid iodine can be obtained from the solid mixture by sublimation. A Bunsen burner is used to heat the mixture gently, allowing solid iodine to sublime. An evaporating dish holds the solid sample so that it can be heated. A filter funnel is inverted so that the gaseous iodine can deposit on the inner surface of the filter funnel. A thermometer is not required as only iodine will sublime.
8. **C**
   The physical properties of sand and water should be considered when separating the mixture. Sand is insoluble in water and hence can be separated from water based on its solubility.
9. **C**
   Volume of acid:

   Experiment 1: 20.80 cm^3

   Experiment 2: 20.90 cm^3

   Experiment 3: 23.10 cm^3

   Since the volume of acid required in experiment 3 deviates significantly from experiments 1 and 2, it cannot be used to calculate the average volume of acid required. Hence, the average volume of acid can be determined by calculating the average of the results of experiments 1 and 2.
10. **B**
    Impurities elevate boiling point of a substance. Hence, impure water would boil at 102 °C.

Level 3

11. **B**
    Since solid calcium carbonate is insoluble in water, it can be separated from sodium chloride solution by filtration (set-up 2). The filtrate can then be evaporated to dryness to obtain pure and dry sodium chloride (set-up 1). Simple distillation (set-up 3) is not used since water is not collected. A magnet (set-up 4) cannot be used as the substances are not magnetic.
12. **D**
    The melting point of sodium chloride is very high such that all the water would have boiled away before sodium chloride melts. The setup will hence be unable to determine the melting point of sodium chloride.
13. **A**
    Since liquified **Y** boils at a fixed temperature, it is a pure substance. Since gas **Y** condenses into a liquid at 0 °C (temperature of ice), it must have a melting point below 0 °C and boiling point above 0 °C.
14. **A**
    The first spot of sample **A** corresponds to the first spot of drug **P**. The second spot of sample **A** corresponds to that of drug **Q**. The first two spots of sample **B** corresponds to that of drug **P**. Sample **B** does not contain drug **Q**.
15. **D**
    A gas syringe can be used to collect and measure the gas produced. A mass balance can be used to measure the mass lost due to carbon dioxide gas escaping the reaction mixture.

    Displacement of water can also be used to collect and measure the volume of carbon dioxide gas produced. Only student **D** is unable to collect and measure the gas produced.

Chapter 2

Level 1

1. **D**
   Distance between particles in a solid (wood) is the closest followed by liquid (liquid zinc and rainwater) and gas (air).
2. **B**
   Cooking oil is a liquid whereby its particles are slightly further apart than those in a solid. Oil particles are denser than air and will take on the shape of the balloon.
3. **B**
   When a solid sublimes, energy is absorbed to overcome forces of attraction to form a gas.

Level 2

4. **B**
Substance **X** is a solid at −140 °C and a gas at −78 °C. This means that its melting point must be above −140 °C (−139 °C or −133 °C) and its boiling point must be below −78 °C (−82 °C or −94 °C).

5. **B**
The substances in a perfume are highly volatile and have low boiling points. This allows the substances to evaporate easily when the perfume is sprayed. The substances do not break down when sprayed and need not necessarily have low density.

6. **A**
Ice melts at 0 °C. Water goes from a solid to a liquid when heated from −20 °C to 15 °C.

7. **C**
The temperature was raised from −110 °C to −65 °C. As only boiling point of substance **C** has not been reached, it will be a solid.

8. **A**
Option A is true. Iodine can undergo sublimation, which is process **III**.

Option B is not true. Sodium chloride is a solid at room temperature as it has a high melting point. It cannot undergo process **V**, which is melting, at room temperature.

Option C is not true. Processes **I**, **VI** and **IV** release energy, not absorb energy.

Option D is not true. A gas would need to be cooled down to deposit into a solid. A solid needs to be heated to sublime to form a gas.

9. **C**
Particles of a liquid and gas are able to move freely whereas particles of a solid can only move about their fixed positions.

10. **C**
Gaseous particles move around randomly at high speeds.

Diagram **A** shows that the gaseous particles are orderly arranged which is incorrect.

Diagrams **B** and **D** show the gaseous particles aggregating at the bottom or top of the container. This is also incorrect since a gas usually occupies the entire volume of the container.

11. **B**
Between t_1 and t_2, particles start to lose energy to the surroundings and slow down. Between t_2 and t_3, a mixture of gas and liquid is present as particles are drawn closer together. At t_3, substance **Y** is a liquid. Between t_4 and t_5, a mixture of liquid and solid is present as the melting point of substance **Y** is achieved. Particles start to move even closer to each other such that they vibrate about fixed positions to form a solid.

Level 3

12. **D**
Both boiling and evaporation involve the absorption of energy to overcome forces of attraction between particles. Evaporation can occur at any temperature in which the substance exists as a liquid. However, evaporation can only take place at the surface of the liquid.

13. **C**
From the graph, all mixtures of **X** and **Y** have melting points that are lower than **Y**.

14. **C**
Statement 1 is not true. Water would have boiled and turned into a gas at 125 °C. Particles of water would have spread further apart, unlike that of **M** at this temperature.

Statement 2 is true. Since water has a lower boiling point than **M**, water would be more likely to evaporate at a faster rate at room temperature.

Statement 3 is not true. Carbon dioxide is a gas at 125 °C. Particles of carbon dioxide would spread further apart unlike that of **M**.

Statement 4 is true. Since the distance between the particles of **M** start to increase significantly at 130 °C, it would mean **M** has achieved its boiling point.

15. **A**
Substance **Z** is stored in tightly sealed containers to prevent the crystals from subliming and hence, "disappearing". **Z** can be either a compound or an element.

Chapter 3

Level 1

1. **D**
A hydrogen atom does not have any neutrons. Since an atom must be electronically neutral, the number of protons must be equal to the number of electrons. The nucleon number of hydrogen is 1, which is equal to its atomic number.

2. **B**
Nucleon number of germanium = 32 + 41 = 73
Proton number of germanium = 32

3. **C**
The identity of an element is always based on the number of protons it has.

4. **C**
Magnesium has an electronic configuration of 2, 8, 2. When a magnesium atom loses 2 electrons, it will have an electronic configuration of 2, 8, which is similar to that of neon.

5. **A**
$^{35}Cl^-$ contains 17 protons, 18 neutrons and 18 electrons. ^{37}Cl contains 17 protons, 20 neutrons and 17 electrons. Hence, both particles contain the same number of protons. $^{35}Cl^-$ has more electrons than ^{37}Cl but fewer neutrons than ^{37}Cl.

6. **D**
Since **X** is in Period 3, it has 3 electron shells. **X** gained 2 electrons to attain the noble gas electronic configuration of 2, 8, 8. This means that the atom of **X** has the electronic configuration 2, 8, 6 and its identity is sulfur. Sulfur has 19 protons and 16 neutrons. So, the S^{2-} ion contains 16 protons, 18 electrons and 16 neutrons.

Level 2

7. **D**
The ion M^{2+} is formed when **M** atoms lose 2 electrons. Number of electrons in the **M** atom = 18 + 2 = 20. The number of protons in **M** atom is also 20. Number of neutrons = 40 − 20 = 20.

8. **D**
Option A is not true. Since the element does not have a noble gas electronic configuration, x cannot be 8.

Option B is not true. Non-metals are mainly located in Groups 14 to 18 in the periodic table. Thus, x must be greater than or equal to 4.

Option C is not true. Since non-metals usually have 4 or more valence electrons, the number of electrons that they can gain would be less than or equal to 4. Hence, the charge on the ion would greater than or equal to –4.

Option D is true. Non-metals usually contain 4 to 8 valence electrons. Hence, the number of electrons gained to attain the noble gas electronic configuration would be less than or equal to 4.

9. **A**
Electrons are negatively charged and hence will be attracted to the positive electric plate. Neutrons have no charge and hence will not be attracted to any of the electric plates. Protons are positively charged and hence will be attracted to the negative plate.

10. **C**
Z is an atom as it has the same number of protons and electrons. **X** has 2 more electrons but the same number of protons as **Z**. Hence, **X** is a negatively charged ion of **Z**.

11. **A**
A hydrogen atom has 1 proton, 1 electron and 1 neutron. Hence, both H^+ and H^- ions do not contain neutrons. The H^+ ion has 1 proton and no electrons while the H^- ion has 1 proton and 2 electrons. Hence, the H^- ion has more electrons than H^+ ion but both have the same number of protons.

Level 3

12. **C**
Number of electrons = number of protons = **X**

In a positive ion, the number of protons remains the same, but the number of electrons is less than **X**. Isotopes contain different numbers of neutrons but the same number of protons. The number of neutrons must be greater or less than **Y**.

13. **D**
Statement 1 is not true. $^{34}_{16}S$ is an atom, not an ion.

Statement 2 is true. All three particles have a greater nucleon number than what is provided in the periodic table, indicating that they are isotopes.

Statement 3 is true. Both $^{40}_{19}K^+$ and $^{37}_{17}Cl^-$ contain a total of 18 electrons which means that they have the same electronic configuration.

Statement 4 is true. $^{34}_{16}S$ contains 18 neutrons, $^{37}_{17}Cl^-$ contains 20 neutrons and $^{40}_{19}K^+$ contains 21 neutrons.

14. **B**
Only Cl^-, Ar and K^+ have the same electronic configuration of 2, 8, 8.

15. **B**
Option A is not true. NH_3 has 10 protons while N_2 has 14 protons.

Option B is true. Both CO and N_2 have 14 protons each.

Option C is not true. Both methane, CH_4, and NH_3 have 10 electrons each.

Option D is not true. N_2 has 14 protons and 14 neutrons.

Chapter 4

Level 1

1. **A**
Atoms form bonds to attain the noble gas electronic configuration.

2. **B**
Both carbon and oxygen are non-metals, so they form bonds by sharing electrons (covalent bonding). An oxygen atom has 6 valence electrons, whereas a carbon atom has 4 valence electrons. Hence, an oxygen atom requires 2 more electrons and a carbon atom requires 4 more electrons to attain the noble gas electronic configuration. Hence, a carbon atom would form bonds with two oxygen atoms. A carbon atom shares 2 electrons with each oxygen atom.

3. **C**
Ionic bonding is formed due to the mutual electrostatic attraction between ions of opposite charges.

4. **B**
Calcium is a metal and hence will lose 2 electrons to form Ca^{2+}. Fluorine is a non-metal and hence will gain 1 electron to form F^- ion.

5. **C**
The element is calcium, which is a metal. Metals do not react with one another and they do not share electrons. Calcium has 2 valence electrons, so it lose 2 electrons to form the ion Ca^{2+}.

6. **D**
Y and **Z** will form a covalent compound by sharing electrons. The formula of the compound formed should be YZ_2.

7. **C**
Bonding electrons = 4 × 2 = 8

Non-bonding electrons = 6 + 2 + 6 = 14

Level 2

8. **B**
Neon, helium and argon are noble gases and hence exist as atoms. Bromine, chlorine, hydrogen, oxygen and nitrogen need to form bonds to attain the noble gas electronic configuration. Hence, they will exist as diatomic molecules with the formula, X_2.

9. **A**
Element **A** has 6 valence electrons, so it is a non-metal in Group 16. Element **B** has 1 valence electron, so it is hydrogen which is a non-metal. Element **D** is a metal in Group 2. Element **E** is a non-metal with 7 valence electrons, so it is from Group 17.

Option A is not true. Elements **A** and **D** will form an ionic compound.

10. **B**
The chemical formula $NiCO_3$ shows that nickel forms ions with a charge of +2. The chemical formula $Al_2(SO_3)_3$ shows that the SO_3 ion has a charge of –2. Hence, the chemical formula of nickel sulfite is $NiSO_3$.

11. **C**
A is potassium whereas **B** is sulfur. Potassium forms ions with a charge of +1 whereas sulfur forms ions with a charge of –2. Hence, the compound would have a chemical formula of A_2B, or K_2S.

Level 3

12. **D**
Zinc nitrate is an ionic compound that contains Zn^{2+} and NO_3^- ions. Since NO_3^- is a polyatomic ion, it contains non-metal atoms that are covalently bonded.

13. **C**
F^-, Ne and Na^+ all have same electronic configuration 2, 8. Hence, they have the same number of electrons.

14. **B**
The covalent bonds between O and Si atoms signify that they share electrons. O atoms have gained electrons from only Na and Ca atoms as Si ions are not present.

15. **B**
Both atoms have attained the noble gas electronic configuration as they have 8 valence electrons each. Since there are 6 electrons shared between C and O, it is a triple bond. One of the bonds consists of 2 electrons from the oxygen atom. The name of the compound is carbon monoxide as there is only one oxygen atom.

Chapter 5

Level 1

1. **B**
Diagram **I** shows two different elements chemically combined, so it is a compound. Diagram **II** shows atoms of two different elements physically combined, making it a mixture. Diagram **III** shows a mixture of compounds and molecules of elements physically combined. Diagram **IV** shows molecules of an element.

2. **C**
Substance **M** cannot be broken down further into simpler substances, so it has to be an element. Substance **N** can be separated by distillation, which is a physical method, so it is a mixture. Substance **O** is a compound formed by heating and chemically combining two elements.

3. **C**
Oxygen exists as simple covalent molecules with weak intermolecular forces of attraction. These weak forces of attraction are easily overcome and hence, oxygen has a low boiling point.

4. **B**
Aluminium oxide is an ionic compound with a giant ionic crystal lattice structure. Strong electrostatic forces of attraction exist between oppositely charged ions, which requires a lot of energy to overcome. Hence, aluminium oxide has high melting and boiling points.

Level 2

5. **D**
X can be separated by filtration, which is a physical separation method, hence it is a mixture. **Y** is a grey solid, which is typical of pure metals. Elemental metals burn in oxygen to form oxides.

6. **C**
Magnesium oxide is an ionic compound with high melting and boiling points. This is due to the strong electrostatic forces of attraction between oppositely charged ions. It can conduct electricity in the liquid and aqueous states when the ions are mobile to act as charge carriers. Sulfur dioxide is a covalent compound with low melting and boiling points. This is due to the weak intermolecular forces of attraction. It cannot conduct electricity in any state due to the absence of mobile ions.

7. **A**
W and **X** do not conduct electricity in any state so they must be covalent substances (S or CO_2). **Y** conducts only when molten so it must be an ionic compound (CaO or BaO). **Z** can conduct in solid and molten state so it could be a metal (Mg).

8. **B**
Magnesium oxide is an ionic compound that consists of magnesium and oxide ions arranged in a giant ionic crystal lattice. Carbon dioxide is a covalent compound that exist as simple covalent molecules. Magnesium carbonate is made up of magnesium and carbonate ions and hence is an ionic compound with a giant ionic crystal lattice structure.

9. **B**
Calcium chloride is able to conduct electricity in the aqueous or liquid/molten state. Calcium chloride is an ionic compound that is soluble in water but insoluble in organic solvents such as hexane.

When dissolved in water, calcium chloride dissociates into mobile ions which act as mobile charge carriers to conduct electricity.

Level 3

10. **A**
Statement 1 is true. Substance **D** has high melting and boiling points and can dissolve in water. So, it could be an ionic compound which dissolves in water to produce mobile ions that act as mobile charge carriers.

Statement 2 is true. Substance **D** could be a pure ionic compound since it melts at a fixed temperature.

Statement 3 is not true. Methane is a covalent compound formed from two non-metals, carbon and hydrogen. It does not have a high melting and boiling point and cannot dissolve in water.

Statement 4 is not true. Substance **D** is not a pure element since burning **D** in oxygen produces two different products.

11. **A**
MgH_2 and KH are ionic compounds so they will have higher melting points than CH_4 and HCl, which are covalent compounds. HCl has a higher melting point than CH_4 as it is a larger molecule with stronger intermolecular forces of attraction. MgH_2 has a higher melting point than KH as the electrostatic forces of attraction between Mg^{2+} and H^- is stronger than that between K^+ and H^-.

12. **A**
E forms cations while **F** forms anions. In the giant ionic crystal lattice structure, eight cations and four anions are present. Hence, the ratio of the cations to the anions is 2 : 1 and the formula of the compound will be E_2F. The identity of the ions will hence be E^+ and F^{2-}.

13. **D**
The disrupted layers of atoms strengthen the metal but does not prevent it from corroding. Since alloys are mixtures, they do not have fixed melting points or fixed chemical formulae. Stainless steel can be used to make utensils as it does not corrode easily.

14. **B**
The compound formed between **W** and **X** is covalent, indicating that both elements **W** and **X** are non-metals. The compound formed between **Y** and **Z** is ionic, with **Y** being a cation and **Z** being an anion. This indicates that **Y** is a metal and **Z** is a non-metal.

Statement 1 is not true. Element **Z** is a non-metal, it does not contain any mobile ions to conduct electricity in the solid state.

Statement 2 is true. The compound formed between **W** and **Y** will be an ionic compound. Ionic compounds can conduct electricity in the molten state as there are mobile ions to act as charge carriers.

Statement 3 is true. The compound formed between **X** and **Z** will be a covalent compound that cannot dissolve in water.

Statement 4 is not true as element **X** is a non-metal that exists as simple covalent molecules.

15. **C**
Statement 1 is incorrect. The structure of **A** represents a giant ionic crystal lattice while the structure of **B** represents a simple covalent molecule. **A** can be sodium chloride, but **B** cannot be hydrogen chloride. This is because **B** contains molecules made up of three atoms.

Statement 2 is correct. **A** cannot conduct electricity in the solid state. This is because its ions in the solid state cannot move freely. **B** cannot conduct electricity in any state due to the absence of mobile ions.

Statement 3 is incorrect. **A** is an ionic compound with a giant ionic crystal lattice structure. Strong electrostatic forces of attraction exist between oppositely charged ions. These forces of attraction require a lot of energy to overcome. Hence, **A** has a high melting and boiling point. **B** is a simple covalent molecule. The weak intermolecular forces of attraction exist do not require a lot of energy to overcome. Hence, **B** has a low melting and boiling point.

Statement 4 is incorrect. Group 2 elements are metals which do not undergo covalent bonding to form compounds like **B**.

Revision Paper 1

1. **B**
The burette is suitable to accurately measure volumes of a liquid to the nearest 0.05 cm^3.

2. **D**
Elements and compounds melt at fixed temperatures. Ice is pure water. Magnesium is an element. Sand is pure silicon dioxide. Steel is a mixture of elements. Hence, it would not have a fixed melting or boiling point.

3. **B**
Impurities generally decrease the melting point and increase the boiling point of a substance.

4. **B**
Sand is insoluble in copper(II) sulfate solution. Hence, filtration can be used to separate the mixture. This allows copper(II) sulfate solution to be collected as the filtrate.

5. **C**
Food flavouring can be analysed using paper chromatography. In paper chromatography, the components are separated as they have different solubilities in the solvent.

6. **C**
Option A is true. The components of drug **Y** travelled further up the chromatogram as compared to the components of drug **W**.

Option B is true. Drugs **X** and **Z** only have one spot each in their chromatogram. Hence, they can be pure compounds.

Option C is not true. The spots in urine sample **A** only matches the spot of drug **X** and one of the spots of drug **Y**.

Option D is true. The spots in urine sample **B** match the spots of both drugs **W** and **Z** in the chromatogram.

7. **A**
The condenser is in an upright position. Hence, it is used to condense any reactant vapours back into the reaction flask. This prevents any reactant vapours from escaping before it is completed.

8. **B**
Carbon dioxide gas is denser than air. Hence, it can be collected by downward delivery. Excess solid limestone can be separated from the reaction mixture by filtration.

9. **D**
Adding water dissolves sodium nitrate, leaving zinc oxide, camphor and sand as the residue. Adding ethanol to the residue dissolves camphor, leaving zinc oxide and sand as the residue. Further separation must be done to separate zinc oxide and sand.

10. **B**
The solubility of **D** increases with temperature. Hence, crystallisation is required to obtain **D**. Crystals of **D** will form when the hot solution of **D** is left to cool down. **E** is highly soluble in water. Its solubility is not greatly affected by the increase in temperature. Hence, evaporation to dryness is required to obtain **E**. **F** is insoluble in water. Hence, **F** can be obtained via filtration.

11. **B**
When a liquid evaporates, particles at the surface of the liquid absorb energy from the surroundings to overcome forces of attraction, allowing these particles to escape as gases.

Particles will go from sliding past each other freely to moving quickly and randomly in any direction.

12. **B**
Oxygen is a solid at –215 °C. When the temperature of the solid was increased to –195 °C, oxygen had melted and boiled. Hence, solid oxygen underwent two state changes from solid to liquid to gas. Argon is a liquid while nitrogen is a solid at –215 °C. –195 °C was too low a temperature to boil argon and melt nitrogen.

13. **C**
Both **A** and **B** have the same number of protons. Hence, they belong to the same element.

14. **D**
Isotopes of the same element have the same chemical properties. So, deuterium compounds have similar chemical formulae as compounds of hydrogen. Since $Zn(OH)_2$ is the correct formula, $Zn(OD)_2$ should be the correct formula for the deuterium compound.

15. **B**
Having the same electronic structure would mean that they have the same number of electrons. After losing the electrons to form their respective cations, Co^{4+}, Cr^{+}, Fe^{3+} and Mn^{2+} all have 23 electrons.

16. **C**
Q is a non-metal from Group 16 since it forms an anion with a charge of –2. **P** has 4 more protons than **Q**, so it will be a metal from Group 2 of the periodic table. Hence, the compound formed between **Q** and **P** is an ionic compound, **PQ**.

17. **C**
Calcium hydride is an ionic compound since it is formed from a metal and a non-metal. Calcium forms ions with a charge of +2 by transferring electrons to two hydrogen atoms. Each hydrogen atom would gain 1 electron to form ions with a charge of –1. Hence, the chemical formula of calcium hydride is CaH_2.

18. **C**
The similarity between solid sodium chloride and aqueous sodium chloride is that both states contain oppositely charged ions. Solid sodium chloride contains ions vibrating in fixed positions.

The distance between particles in aqueous sodium chloride is further than that in solid sodium chloride.

The particles in aqueous sodium chloride slide over each other freely and do not move quickly and randomly in any direction.

19. **D**
X is a non-metal that forms anions with a charge of –2. Hence, it is an element from Group 16 of the periodic table.

20. **B**
Option A is correct. The bond between potassium ion and hydroxide ion is ionic. The bond between oxygen and hydrogen within the hydroxide ion is covalent.

Option B is not correct. Calcium forms ions with a charge of +2. Hence, it forms ionic bonds with two hydroxide ions.

Option C is correct. Since the hydroxide ion is an anion, it could have gained an electron from a metal like sodium.

Option D is correct. The OH^- ion is more stable since all the atoms have attained the noble gas stable electronic configuration. In the OH molecule, oxygen has only 7 valence electrons.

21. **D**
The nitrogen atom in nitrogen monoxide has only 7 valence electrons. For the molecule to be stable, nitrogen must attain the noble gas electronic configuration by gaining 1 electron. Dissolving it in water does not stabilise it. A hydrogen atom could form a covalent bond with the nitrogen atom, stabilising the molecule. Potassium could lose 1 electron to nitrogen monoxide, stabilising the molecule. Two nitrogen monoxide molecules could form a covalent bond with each other, stabilising both molecules.

22. **D**
The size of the substance is not a substantial factor when determining the melting and boiling points of ionic and covalent substances. During melting and boiling, the electrostatic forces of attraction in potassium iodide and intermolecular forces of attraction in iodine are overcome. A large amount of energy is required to overcome the electrostatic forces of attraction between oppositely charged ions in potassium iodide whereas a small amount of energy is required to overcome intermolecular forces of attraction between iodine molecules.

23. **C**
Substance **X** is iodine. Iodine can sublime and hence solid iodine "disappears" when heated gently.

Iodine will combine with potassium to form an ionic compound called potassium iodide.

Statement 1 is true as iodine exist as diatomic molecules with the formula I_2.

Statement 2 is not true. Iodine has seven valence electrons and hence would only require to form one bond with one hydrogen atom to form a compound with the formula HI.

Statement 3 is not true. Potassium iodide is an ionic compound that can only conduct electricity in the molten or aqueous state.

Statement 4 is true. When heated gently, iodine sublimes. Particles in solid iodine vibrate about fixed positions. Once heated, particles gain energy and start to move around randomly at high speeds to form iodine gas.

24. **D**
Statement 1 is not true. **I** is a compound, but it cannot be ammonia as there are 4 atoms in ammonia (NH_3).

Statement 2 is true. **II** shows the structure of a pure solid whereas **IV** shows a simple diatomic molecule of an element. Hence, their identities could be magnesium and hydrogen respectively.

Statement 3 is not true while statement 4 is true. **III** shows the structure of an alloy which is formed by mixing a metal and another element. Hence, **I** cannot be used to form an alloy.

Statement 5 is true. **I, II** and **IV** represent pure substances. So, they will have fixed boiling points.

25. **B**
Statement 1 is true. At 300 °C, **E** is a gas, while **F** is a liquid and **G** is a solid. The distance between particles in a solid are the shortest followed by liquid and then gas.

Statement 2 is not true. At room temperature, **E** is a gas while **F** and **G** are solids. So, only **F** and **G** contain particles that are vibrating about fixed positions.

Statement 3 is not true. **E** is a covalent compound with low melting and boiling points while **F** is an ionic compound with high melting and boiling points. Zinc can only form ionic compounds.

Statement 4 is true. **G** is a good conductor of electricity in the solid state. So, it is a metal and could be magnesium.

Chapter 6

Level 1

1. **D**
Oxides are compounds of oxygen. O_2 is an element.

2. **A**
Ca forms ionic compounds with a charge of +2 while Se forms ions with a charge of –2. The chemical formula between Ca and Se should be CaSe.

3. **D**
The element with the atomic number of 12 is magnesium. The element with the atomic number of 15 is phosphorus. Mg^{2+} and P^{3-} will form magnesium phosphide, Mg_3P_2.

4. **D**
The balanced equation is $N_2 + 3H_2 \longrightarrow 2NH_3$.

5. **D**
S_2O_3 ion has a charge of –2. Aluminium forms ions with a charge of +3. Hence, the compound formed will be $Al_2(S_2O_3)_3$.

6. **B**
Chemical equation:

$(NH_4)_2SO_4(aq) + 2KOH(aq) \longrightarrow K_2SO_4(aq) + 2NH_3(g) + 2H_2O(l)$

Ionic equation:

$2NH_4^+(aq) + 2OH^-(aq) \longrightarrow 2NH_3(g) + 2H_2O(l)$

$NH_4^+(aq) + OH^-(aq) \longrightarrow NH_3(g) + H_2O(l)$

Level 2

7. **A**
Let the charge on the Si_2O_7 ion be x.

H_2O is a neutral molecule, so it has no charge. Calcium and aluminium form ions with a charge of +2 and +3 respectively. OH ion has a charge of –1. The compound is electrically neutral. Hence,

$(+2) + 2(+3) + x + 2(-1) = 0,$

$+8 + x - 2 = 0$

$x = -6$

8. **D**
Option A is correct since $Ca(NO_3)_2$ exists.

Option B is correct since Na_3N exists.

Option C is correct since NH_3 exists.

Option D is wrong as Zn^{2+} and NO_3^- ions would combine to form $Zn(NO_3)_2$, not $ZnNO_3$.

9. **B**
Chemical equation:
$Zn(s) + 2HNO_3(aq) \longrightarrow Zn(NO_3)_2(aq) + H_2(g)$
Ionic equation:
$Zn(s) + 2H^+(aq) + \cancel{2NO_3^-(aq)} \longrightarrow Zn^{2+}(aq) + \cancel{2NO_3^-(aq)} + H_2(g)$
$Zn(s) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + H_2(g)$

10. **B**
X forms ions with a charge of +3 whereas **Y** forms ions with a charge of –1. Hence, the products formed will be XY_3 and Na_2SO_4.

11. **C**
The balanced equation is
$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$.

12. **B**
Chemical equation:
$CuCl_2(aq) + 2NaOH(aq) \longrightarrow Cu(OH)_2(s) + 2NaCl(aq)$
Ionic equation:
$Cu^{2+}(aq) + \cancel{2Cl^-(aq)} + \cancel{2Na^+(aq)} + 2OH^-(aq) \longrightarrow Cu(OH)_2(s) + \cancel{2Na^+(aq)} + \cancel{2Cl^-(aq)}$
$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

13. **D**
Calcium decomposes according to the equation $CaCO_3 \longrightarrow CaO + CO_2$.
Hence, solid **X** is calcium oxide, CaO. Calcium oxide reacts with nitric acid according to the equation $CaO + 2HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O$.
Hence, solution **Y** is calcium nitrate, $Ca(NO_3)_2$.

Level 3

14. **C**
Options A and B are not balanced.
Option D produces oxygen atoms which do not exist as they are unstable.

15. **D**
At room temperature, all the substances in the reaction exist as gases except for water.

Chapter 7

Level 1

1. **B**
Number of moles of ammonia
$= \frac{1.7}{(14 + 3 \times 1)} = 0.100$ mol
Number of moles of carbon dioxide
$= \frac{2.2}{(12 + 2 \times 16)} = 0.0500$ mol
Number of moles of magnesium chloride
$= \frac{19}{(24 + 2 \times 35.5)} = 0.200$ mol
Number of moles of lead
$= \frac{20.7}{207} = 0.100$ mol

2. **D**
The three gases have the same volume of 100 cm^3. Thus, they have the same number of moles. Even though the gases have the same number of moles, they have different molar masses. Thus, they have different masses. Since the gases have the same number of moles, it means that they also have the same number of molecules as 1 mol = 6.02×10^{23} particles.

3. **A**
Mass of hydrogen
$= 0.5 \times 2 = 1.00$ g
Mass of helium
$= 0.5 \times 4 = 2.00$ g
Hence, helium has a greater mass than hydrogen.
Mass of carbon dioxide
$= 0.6 \times 44 = 26.4$ g
Mass of argon
$= 0.6 \times 40 = 24.0$ g
Hence, carbon dioxide has a greater mass than argon.
Mass of calcium chloride
$= 0.6 \times 111 = 66.6$ g
Mass of sodium oxide
$= 0.8 \times 62 = 49.6$ g
Hence, calcium chloride has a greater mass than sodium oxide.
Mass of sodium hydroxide
$= 0.7 \times 40 = 28.0$ g
Mass of nitrogen
$= 0.8 \times 28 = 22.4$ g
Hence, sodium hydroxide has a greater mass than nitrogen.

4. **B**
M_r of $FeCO_3 = 56 + 12 + 48 = 116$
Number of moles of $FeCO_3$
$= 52 \div 116 = 0.4483$ mol
Based on the equation, 1 mol of $FeCO_3$ decomposes to form 1 mol of CO_2.
Volume of CO_2 produced
$= 0.4483 \times 24 = 10.8$ dm^3

5. **D**
M_r of $XF_3 = 27 \div 0.25 = 108$
M_r of Fluorine in $XF_3 = 19 \times 3 = 57$
M_r of **X** in $XF_3 = 108 - 57 = 51$
Hence, **X** is vanadium.

Level 2

6. **D**
Number of moles of H_2SO_4
$= \frac{25}{1000} \times 0.5 = 0.0125$ mol
From the equation, 1 mol of H_2SO_4 reacts with 2 mol of KOH.
Number of moles of KOH required to completely react with H_2SO_4
$= 0.0125 \times 2 = 0.0250$ mol
Concentration of KOH
$= 0.0250 \div \frac{20}{1000} = 1.25$ mol/dm^3

7. **A**

Number of moles of Zn
$= 1.3 \div 65 = 0.0200$ mol

Number of moles of HNO_3
$= 0.8 \times \frac{20}{1000} = 0.0160$ mol

From the equation, 1 mol of Zn reacts with 2 mol of HNO_3. 0.0200 mol of Zn reacts with 0.0400 mol of HNO_3. Since only 0.0160 mol of HNO_3 is present, it is the limiting reactant.

Number of moles of H_2 produced
$= \frac{1}{2} \times 0.0160 = 0.00800$ mol

Volume of H_2 produced
$= 0.00800 \times 24\ dm^3 = 0.192\ dm^3$
$= 192\ cm^3$

8. **C**

M_r of $\mathbf{X}_2O = \frac{49.6}{0.8} = 62$

M_r of $\mathbf{X} = \frac{62 - 16}{2} = 23$

M_r of $\mathbf{Y}_2(SO_4)_3 = \frac{68.4}{0.2} = 342$

M_r of $\mathbf{Y} = \frac{342 - 3(32 + 4 \times 16)}{2} = 27$

M_r of $\mathbf{Z}Cl_2 = \frac{47.5}{0.5} = 95$

M_r of $\mathbf{Z} = 95 - (2 \times 35.5) = 24$

Hence, atomic mass:

$\mathbf{Y} > \mathbf{Z} > \mathbf{X}$

9. **B**

Number of moles of copper(II) oxide
$= \frac{25}{(64 + 16)} = 0.3125$ mol

Number of moles of sulfuric acid
$= \frac{200}{1000} \times 1.0 = 0.200$ mol

1 mol of copper(II) oxide reacts with 1 mol of sulfuric acid. 0.3125 mol of copper(II) oxide would hence require 0.3125 mol of sulfuric acid for complete reaction. Since only 0.200 mol of sulfuric acid is present, it is the limiting reactant.

Mass of copper(II) sulfate formed
$= 0.200 \times (64 + 32 + 4 \times 16) = 32.0$ g

Level 3

10. **A**

Number of moles of $CuCl_2$
$= \frac{30}{1000} \times 0.5 = 0.0150$ mol

Number of moles of NaOH
$= \frac{30}{1000} \times 0.5 = 0.0150$ mol

From the equation, 1 mol of $CuCl_2$ reacts with 2 mol of NaOH.

Theoretical number of moles of NaOH
$= 2 \times 0.0150 = 0.0300$ mol

Since only 0.0150 mol of NaOH is present, it is the limiting reactant.

$CuCl_2$ is present in excess in the solution together with the product NaCl. As $Cu(OH)_2$ is insoluble, it will not produce any ions in solution. Thus, the ions present in the solution after the reaction are Cl^-, Cu^{2+} and Na^+.

11. **B**

Number of moles of O atoms
$= 8 \div 16 = 0.500$ mol

Based on the chemical formula $\mathbf{Z}_3O_4$,

mole ratio of O : **Z** = 4 : 3

Number of moles of **Z** atoms
$= \frac{3}{4} \times 0.500 = 0.375$ mol

Mass of **Z** = 29 − 8 = 21 g

M_r of **Z** = 21 ÷ 0.375 = 56

Hence, metal **Z** is iron.

12. **B**

M_r of SO_4^{2-}
$= 32 + (4 \times 16) = 96$

Number of moles of SO_4^{2-} ions
$= 19.2 \div 96 = 0.200$ mol

$Mg^{2+} + SO_4^{2-} \longrightarrow MgSO_4$

Hence, number of moles of $MgSO_4$
$= 0.200$ mol

Number of moles of Mg^{2+} ions present in mixture
$= 9.6 \div 24 = 0.400$ mol

Number of moles of Mg^{2+} ions present in $MgCl_2$
$= 0.400 - 0.200 = 0.200$ mol

Number of moles of Cl^- ions in $MgCl_2$
$= 0.200 \times 2 = 0.400$ mol

Number of moles of Cl^- ions present in mixture
$= 35.5 \div 35.5 = 1.00$ mol

Number of moles of Cl^- ions in $AlCl_3$
$= 1.00 - 0.400 = 0.600$ mol

Number of moles of Al^{3+} ions in $AlCl_3$
$= 0.600 \div 3 = 0.200$ mol

13. **C**

Mass of $H_2O = 10.00 - 6.40 = 3.60$ g

Number of moles of H_2O present
$= 3.60 \div 18 = 0.200$ mol

Mass of $Fe_2O_3 = 6.40$ g

Number of moles of Fe_2O_3
$= \frac{6.40}{(56 \times 2) + (3 \times 16)} = 0.0400$ mol

Mole ratio of $Fe_2O_3 : H_2O$
$= 0.0400 : 0.200 = 1 : 5$

Hence, $z = 5$.

14. **B**

When cooled to room temperature, gaseous H_2O condenses to become liquid H_2O.

M_r of $C_2H_6 = (12 \times 2) + (6 \times 1) = 30$

Number of moles of $C_2H_6 = 3 \div 30 = 0.100$ mol

Number of moles of $O_2 = 10.2 \div 24 = 0.425$ mol

From the equation, 2 mol of C_2H_6 reacts with 7 mol of O_2.

Number of moles of O_2 required to completely react with 0.100 mol of $C_2H_6 = \frac{7}{2} \times 0.100 = 0.350$ mol

O_2 is in excess and C_2H_6 is the limiting reactant.

Number of moles of O_2 in excess
$= 0.425 - 0.35 = 0.0750$ mol
Volume of O_2 in excess
$= 0.0750 \times 24 = 1.80\ dm^3$
From the equation, 2 mol of C_2H_6 reacts to form 4 mol of CO_2.
Number of moles of CO_2 formed
$= \frac{4}{2} \times 0.100 = 0.200$ mol
Volume of CO_2 formed
$= 0.200 \times 24 = 4.80\ dm^3$
Total volume of gases in the vessel after cooling down
$= 4.80 + 1.80 = 6.60\ dm^3$

15. **B**
Number of moles of $MgCO_3$ decomposed
$= \frac{250 \times 10^6}{24 + 12 + 3 \times 16} = 2.98 \times 10^6$ mol
From the equations,
Mole ratio of $MgCO_3 : MgO = 1 : 1$
Mole ratio of $MgO : Si = 2 : 1$
Number of moles of Si reacted
$= \frac{2.98 \times 10^6}{2} = 1.49 \times 10^6$ mol
Mass of Si reacted
$= 1.49 \times 10^6 \times 28$
$= 41.7 \times 10^6\ g = 41.7$ tonnes

Chapter 8

Level 1

1. **D**
Ammonia reacts with an acid to form a salt and water.
Ammonium nitrate reacts with an alkali to form a salt, water and ammonia gas.
Calcium carbonate reacts with an acid to form a salt, water and carbon dioxide gas.
Zinc oxide is an amphoteric oxide which reacts with both an acid and an alkali.

2. **A**
When an acid reacts with an alkali, the hydrogen ions produced by the acid react with the hydroxide ions produced by the alkali to form water. This is a neutralisation reaction which is shown by the ionic equation: $H^+ + OH^- \longrightarrow H_2O$

3. **A**
Calcium oxide is a basic oxide that can be used to neutralise acidic soil. Magnesium chloride and zinc nitrate are neutral salts while sulfur dioxide is an acidic oxide.

4. **C**
Carbon dioxide (CO_2), an acidic oxide, and lead(II) oxide (PbO), an amphoteric oxide, can react with potassium hydroxide, an alkali. Barium oxide (BaO), an alkaline oxide, and water (H_2O), a neutral oxide, cannot react with potassium hydroxide.

5. **B**
Sulfuric acid behaves as an acid when it produces hydrogen ions in an aqueous solution. The hydrogen ions react with the hydroxide ions from sodium hydroxide to form a solution with a pH of 7.

Level 2

6. **A**
Statement 1 is correct. Sodium oxide is a soluble basic oxide which dissolves in water to form the alkali sodium hydroxide.
Statement 2 is incorrect. Sodium chloride is a neutral salt which does not react with sodium hydroxide. Hence, the pH of the resultant solution does not decrease to 7.
Statement 3 is incorrect. Zinc oxide is an amphoteric oxide. Thus, it reacts with an alkali such as sodium hydroxide.

7. **B**
Hydrogen chloride is an acidic gas which dissolves in water to form hydrochloric acid. Thus, changing the solvent from benzene to water will allow hydrogen chloride gas to form hydrochloric acid in water. The acid will then react with zinc carbonate to produce carbon dioxide gas.

8. **B**
Option A is not true. Ammonium carbonate reacts with hydrochloric acid to form ammonium chloride, water and carbon dioxide gas. However, it does not react with aqueous ammonia.
Option B is true. Hydrochloric acid is acidic and thus has a lower pH value than alkalis. Ammonia is a weak alkali and hence has a lower pH than sodium hydroxide which is a strong alkali.
Option C is not true. Copper(II) oxide is a basic oxide. Thus, it only reacts with ethanoic acid but not with aqueous ammonia.
Option D is not true. Hydrochloric acid and aqueous ammonia have different acidity. Thus, Universal Indicator shows different colours when added into both solutions.

9. **C**
Ammonia gas dissolves in water and produces hydroxide ions in the aqueous solution.
$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
Thus, the resultant solution is alkaline.
From the equation above, ammonia does not react with water to form ammonium hydroxide.
As the resultant solution is alkaline, it does not react with iron(II) oxide which is a basic oxide. It also does not turn blue litmus paper red.

Level 3

10. **B**
Adding calcium carbonate into dilute nitric acid produces calcium nitrate, water and carbon dioxide gas.
Adding copper metal into acids does not result in any reaction since copper is an unreactive metal. Thus, no gas is produced.
Sulfur dioxide is an acidic oxide which dissolves in water to form sulfurous acid. The acid formed reacts with zinc to produce hydrogen gas.
Mixing ammonium chloride with potassium hydroxide produces potassium chloride, water and ammonia gas.

11. **C**
Potassium nitrate is a neutral salt while sulfuric acid is acidic. Thus, the resultant mixture is acidic. This shows that indicator **Q** is red in acidic solutions. Thus, **Y** is red.
When equal amounts of indicators **P** and **Q** were added to hydrochloric acid, the colour of the solution was orange. Since indicator **Q** is red in acidic solutions, indicator **P** is likely to be yellow to form an orange solution with indicator **Q**. Thus, **W** is yellow.

Ammonia, which is alkaline, turned indicator **P** blue. Thus, **X** is blue.

A mixture of indicators **P** and **Q** in sodium hydroxide is blue. Thus, indicator **Q** is likely to be blue in alkaline solutions. Thus, **Z** is blue.

12. **A**

$2KOH + H_2SO_4 \longrightarrow K_2SO_4 + 2H_2O$

Molar mass of KOH

$= 39 + 16 + 1$

$= 56$

Number of moles of KOH $= \frac{28}{56} = 0.500$ mol

From the equation, 1 mol of H_2SO_4 reacts with 2 mol of KOH.

Thus, number of moles of KOH that reacts with 0.2 mol of $H_2SO_4 = 2 \times 0.2 = 0.4$ mol

Since 0.5 mol of KOH was added, it is in excess.

After neutralisation between potassium hydroxide and sulfuric acid took place, the excess potassium hydroxide dissolved in the solution, thus increasing the pH of the resultant mixture and causing the Universal Indicator solution to turn blue.

13. **A**

Both aluminium oxide and zinc oxide are insoluble in water. Thus, upon neutralisation at pH 7, adding aluminium oxide or zinc oxide to sulfuric acid does not further increase the pH of the reaction mixture. Sodium oxide is a soluble oxide. Thus, it dissolves in sulfuric acid. When sodium oxide is added in excess, the pH of the reaction mixture becomes greater than 7.

14. **B**

Statement 1 is true. Like carbon dioxide, sulfur dioxide reacts with limewater (calcium hydroxide) to form insoluble calcium sulfite.

Statement 2 is not true. Calcium chloride is a neutral salt which does not react with sulfur dioxide.

Statement 3 is not true. Calcium carbonate does not react with aqueous ammonia. Since calcium sulfite has similar chemical properties as calcium carbonate, it is not likely to react with aqueous ammonia.

Statement 4 is true. Calcium carbonate reacts with hydrochloric acid to form calcium chloride, carbon dioxide and water. Similarly, calcium sulfite reacts with hydrochloric acid to form calcium chloride, sulfur dioxide and water.

15. **C**

Both aluminium oxide and magnesium carbonate react with nitric acid to form soluble aluminium nitrate and magnesium nitrate respectively.

Only magnesium carbonate reacts with nitric acid to give off carbon dioxide gas.

Magnesium carbonate does not react with sodium hydroxide. Aluminium oxide, an amphoteric oxide, reacts with sodium hydroxide.

Chapter 9

Level 1

1. **C**

Silver hydroxide is insoluble and hence is not an alkali. Sodium hydroxide reacts with nitric acid to form soluble sodium nitrate. Barium hydroxide reacts with sulfuric acid to form white barium sulfate precipitate. Calcium chloride is not an alkali.

2. **B**

A burning splint, a glowing splint and limewater are used to test for hydrogen gas, oxygen gas and carbon dioxide gas respectively. Damp blue litmus paper turns red in the presence of hydrogen chloride and chlorine gas but will be bleached in the presence of chlorine gas.

3. **B**

Aluminium hydroxide and zinc hydroxide are amphoteric hydroxides. Amphoteric hydroxides react with both alkalis and acids. Aluminium hydroxide is insoluble in excess aqueous ammonia and hence is not soluble in excess alkali.

4. **C**

If nitrate ions are present in the solution, ammonia gas will be produced when aluminium and aqueous sodium hydroxide is added into the solution and heated. Damp red litmus paper will be used to identify the ammonia gas produced.

5. **B**

Calcium ions and ammonium ions do not produce any precipitates when aqueous ammonia is added. Iron(II) ions and zinc ions will produce precipitates. Hence, only calcium nitrate and ammonium iodide solution will have no observations when aqueous ammonia is added.

Level 2

6. **D**

Gas **A** is carbon dioxide.

Statements 1 and 2 are true. Carbon dioxide is an acidic gas and hence would be able to react with bases. Sodium hydroxide and calcium oxide are bases.

Statement 3 is true since acidic gases turn damp blue litmus paper red.

7. **B**

A white precipitate is formed when acidified silver nitrate solution is added to solution **B**. This is a positive test for chloride ions. When excess aqueous sodium hydroxide is added, a white precipitate that is insoluble in excess aqueous sodium hydroxide is formed. This is a positive test for calcium ions. Effervescence is observed when the resultant solution is heated which confirms that ammonium ions are present.

8. **A**

Aluminium nitrate forms a white precipitate in aqueous ammonia that is insoluble in excess.

Copper(II) sulfate forms a light blue precipitate that dissolves in excess aqueous ammonia. Sodium hydroxide does not produce any precipitates but dissolves in the water present in aqueous ammonia. Zinc hydroxide dissolves in excess aqueous ammonia.

9. **C**

Adding an acid and observing effervescence is a positive test for carbonate ions. A coloured precipitate is formed when excess aqueous sodium hydroxide was added. So, the cation could be copper(II), iron(II) or iron(III) ions. The colour of iron(II) ions in solution is green.

Level 3

10. **B**

Hydrogen peroxide decomposes into oxygen and water. Product **J** is hence oxygen gas. Oxygen gas can be identified using a glowing splint. It is a neutral gas that dissolves in water to form a neutral solution. It does not change the colour of litmus papers. When combined with carbon, carbon dioxide is formed. Carbon dioxide produces a white precipitate when bubbled into limewater.

11. **A**
Gas **X** is hydrogen. Hydrogen reacts with oxygen to form water, which is a colourless liquid that boils at 100 °C. A burning splint is used to identify hydrogen gas. The burning splint is extinguished with a "pop" sound in the presence of hydrogen gas.

Gas **Y** is carbon dioxide. Limewater is used to test for carbon dioxide gas. When carbon dioxide is bubbled into limewater, a white precipitate of calcium carbonate is observed.

Gas **Z** is oxygen since it can react with carbon to form carbon dioxide. A glowing splint is used to identify oxygen gas. The glowing splint is rekindled in the presence of oxygen gas.

12. **A**
Potassium carbonate and nitric acid will produce an effervescence of carbon dioxide. When barium chloride is added to copper(II) sulfate, a white precipitate of barium sulfate is formed. No observations can be seen when nitric acid is added to sodium hydroxide. A blue precipitate of copper(II) hydroxide is formed when copper(II) sulfate is added to sodium hydroxide.

13. **C**
Adding aqueous sodium hydroxide to zinc chloride solution forms a white precipitate which dissolves in excess sodium hydroxide. This would correspond to **I**.

When aqueous sodium hydroxide is added to copper(II) sulfate solution, a blue precipitate is formed. This precipitate is insoluble in excess aqueous sodium hydroxide. Hence, this would correspond to **II**.

14. **C**
Since green precipitate **D** turns into brown solid **E** on standing, **C** and **D** would contain Fe^{2+} ions and **E** would contain Fe^{3+} ions. To form green precipitate **D**, an alkali gas such as NH_3 should be bubbled into solution **C**. Therefore, **A** contains NH_4^+ ions and **B** is NH_3.

15. **D**
Alkalis react with ammonium salts to give off ammonia gas. Ammonium ions do not form a precipitate when aqueous sodium hydroxide is added. Therefore, another cation like zinc or aluminium is present in the solution. The precipitate formed could hence be either zinc hydroxide or aluminium hydroxide.

Chapter 10

Level 1

1. **B**
An oxidising agent like acidified potassium manganate(VII) can be used to identify sulfur dioxide.

Level 2

2. **A**
The oxidation state of hydrogen in H_2O_2 is +1. Since there are 2 oxygen atoms in H_2O_2, the oxidation state of oxygen in H_2O_2 is –1.

3. **B**
CH_4 is oxidised as the oxidation state of carbon increases from –4 in CH_4 to +4 in CO_2. O_2 is reduced as the oxidation state of oxygen decreases from 0 in O_2 to –2 in CO_2 or H_2O.

4. **C**
Potassium has an oxidation state of +1.

Oxygen has an oxidation state of –2.

Let the oxidation state of V in $K_2V_2O_5$ be x.

$2(+1) + 2x + 5(-2) = 0$

$2 - 10 + 2x = 0$

$2x - 8 = 0$

$x = +4$

5. **B**
Chlorine is reduced by I^- as the oxidation state of chlorine decreases from 0 in Cl_2 to –1 in Cl^-.

6. **C**
The oxidation state of hydrogen increases from 0 in H_2 to +1 in H_2O. This shows that hydrogen has lost electrons when forming water.

The oxidation state of oxygen decreases from 0 in O_2 to –2 in H_2O. This shows that oxygen has gained electrons when forming water.

Since hydrogen is oxidised and oxygen is reduced, the formation of water is a redox reaction.

7. **B**
Option A: 0 in Cl_2 to –1 in HCl and +1 in HOCl

Option B: +7 in MnO_4^- to +2 in Mn^{2+}

Option C: +1 in NaClO to +3 in $NaClO_2$ and –1 in NaCl

Option D: 0 in S to +4 in SO_2

8. **D**
Hydrogen peroxide can act as both an oxidising agent and a reducing agent. When acidified potassium manganate(VII) reacts with hydrogen peroxide, the purple solution decolourises. When acidified potassium iodide reacts with hydrogen peroxide, the colourless solution turns brown.

9. **C**
Fe reduced Fe^{3+} to Fe^{2+} and is also oxidised to Fe^{2+}.

Level 3

10. **B**
Oxidation state of Cr:

CrO: +2

CrO_2: +4

Cr_2O_3: +3

CrO_3: +6

Cr: 0

The greatest increase in oxidation occurs when Cr_2O_3 is oxidised to CrO_3 where the oxidation state of chromium increases from +3 to +6.

11. **C**
The oxidation state of hydrogen remains unchanged in hydrogen peroxide and water. The oxidation state of oxygen is –1 in H_2O_2, –2 in H_2O and 0 in O_2. Hence, oxygen in hydrogen peroxide is oxidised to form oxygen gas and is also reduced to form water.

12. **D**
The oxidation state of hydrogen remains unchanged in H^+ and H_2O. I^- is oxidised as the oxidation state of iodine increases from –1 in I^- to 0 in I_2. The oxidation state of iodine decreases from +5 in IO_3^- to 0 in I_2. I^- is the reducing agent while IO_3^- is the oxidising agent. Since H^+ is involved in reaction, the concentration of H^+ ions decreases. This causes the pH to increase.

13. **A**
MnO_4^- ions are purple in colour, whereas Mn^{2+} ions are colourless. Hence, acidified potassium manganate(VII) turns from purple to colourless. MnO_4^- ions are purple in colour and they decolourise when Mn^{2+} ions are formed.

14. **B**
The oxidation state of rubidium is always +1. Hence, the oxidation state of oxygen in the following compounds is as follows: RbO_2: –0.5; Rb_2O_2: –1; Rb_2O: –2.

15. **C**
Option A is not correct while option C is correct. Bromine cannot oxidise potassium chloride to chlorine whereas chlorine can oxidise potassium bromide to bromine. So, chlorine is a stronger oxidising agent than bromine.

Option B is not correct. Chlorine is reduced when it forms potassium chloride. Hence, it acts as an oxidising agent.

Option D is not correct. Since bromine can oxidise potassium iodide to iodine, and chlorine is a stronger oxidising agent than bromine, it can also oxidise potassium iodide to iodine.

Chapter 11

Level 1

1. **D**
Alkali metals are stored in oil, not in an inert atmosphere containing a noble gas.

2. **A**
Option A is false. Bromine does not sublime when heated. The only Group 17 element that sublimes is iodine.

Option B is true. Chlorine has a lower boiling and melting point than iodine. Hence, it exists as a gas while iodine exists as a solid at room temperature.

Option C is true. Group 1 metals like sodium and potassium are very reactive and will react quickly with oxygen and water vapour in the air. Hence, they are stored in oil.

Option D is true. Since potassium is more reactive than sodium, its reaction with water is more vigorous.

3. **C**
The reactivity of halogens decreases down Group 17.

Level 2

4. **C**
The metallic properties of the elements decrease across a period as metals are grouped on the left-hand side whereas the non-metals are grouped on the right-hand side. Since the metallic properties of an atom is inversely related to the size of the atom, this shows that the size of the atoms decreases across the period. The nature of the oxides of the elements changes from basic to amphoteric to acidic. The valency of an element increases from lithium to carbon, then decreases from carbon to neon.

5. **D**
Option A is true. Since the ions of element **B** is converted into element **B**, element **B** has been displaced by element **A**. Hence, element **A** is more reactive than element **B**.

Option B is true as chlorine is more reactive than bromine so chlorine is able to displace bromide ions to form bromine.

Option C is true. Fluorine, chlorine and bromine are all more reactive than iodine and hence are able to displace iodide ions to form iodine.

Option D is not true. Potassium is more reactive than lithium and hence lithium is unable to displace potassium ions.

6. **B**
Option B is correct. Chlorine is below fluorine in the periodic table. Hence, it has a higher melting and boiling point than fluorine.

Options A and C are wrong. Argon and oxygen exist as gases while magnesium and aluminium exist as solids at room temperature. Hence, argon and oxygen have lower melting and boiling points than magnesium and aluminium respectively.

Option D is wrong. Rubidium is below sodium in the periodic table. Hence, it has a lower melting and boiling point than sodium.

7. **D**
Potassium iodide solution is colourless. When chlorine gas is bubbled into the solution, the solution turns brown. This is because chlorine is more reactive and can displace iodine from potassium iodide. Iodide ions are oxidised to iodine while chlorine is reduced to chloride ions.

8. **A**
Since the reactivity of Group 16 elements decreases down the group, oxygen is the most reactive element in Group 16. Since the reactivity of Group 1 elements increases down the group, rubidium is the most reactive element provided in the options. Hence, oxygen and rubidium would react the most vigorously.

9. **D**
Option A is wrong. Both **X** and **Y** cannot be elements in Group 2 as they both form ions with a charge of +1, not +2. Therefore, **X** and **Y** are elements in Group 1 of the periodic table.

Option B is wrong. **Y** cannot be lithium as it is the least reactive element in Group 1. Therefore, it cannot displace sodium from sodium chloride solution.

Option C is wrong. When heated in oxygen, **Y** forms Y_2O while **X** forms X_2O. **YO** is not formed.

Option D is correct. The melting and boiling points of elements decrease down Group 1 of the periodic table. Since **Y** displaces **X** from **XCl**, **Y** is a more reactive element than **X**. As such, it will also have a lower melting point than **X**.

10. **B**
Since the oxide of element **E** can react with both acids and alkalis, it is an amphoteric oxide. Therefore, it is likely located in Group 13 of the periodic table.

Element **F** reacts with water to form a compound with the formula **FOH**, which is similar to the reaction of Group 1 elements. Hence, element **F** is likely to be a Group 1 element.

Elements **E** and **G** react to form an ionic compound with the formula EG_3. This indicates that **G** is a non-metal that forms ions with a charge of –1. Hence, **G** is likely a Group 17 element.

Therefore, the order of atomic number is:

F < E < G

Level 3

11. **D**
Unine forms compounds with magnesium of the formula $MgUn_2$. This indicates that unine forms ions with a charge of –1. Hence, unine is likely in Group 17 of the periodic table. Since unine is a dark liquid, it is likely between bromine and iodine in the periodic table. Since the reactivity of Group 17 elements decreases down the group, unine would be able to displace iodine from potassium iodide but not chlorine from potassium chloride.

12. **B**
The equation $X + Y^{2+} \longrightarrow X^{2+} + Y$ shows that **X** displaces **Y** from its solution. Hence, **X** is more reactive than **Y**. The equation $3X + 2Z^{3+} \longrightarrow 3X^{2+} + 2Z$ shows that **X** displaces **Z** from its solution. Hence, **X** is more reactive than **Z**. For **Y** to be more reactive than **Z**, **Y** has to displace **Z** from its solution. So, the equation will be $3Y + 2Z^{3+} \longrightarrow 3Y^{2+} + 2Z$.

13. **A**
Since element **H** has 7 valence electrons, it is in Group 17 in the periodic table. When element **J** is added into a solution of **KH**, a red-brown solution is formed. This shows that element **J** displaced **H** from its solution. Since the resultant solution is red-brown, element **H** is likely to be bromine. **J** could be either chlorine or fluorine since they are both more reactive than bromine.

14. **C**
Reactivity increases down Group 2. If **Z** is below calcium in the periodic table, **Z** would be more reactive than calcium but would be less reactive than strontium. **Z** would thus be able to displace Ca^{2+} ions, while strontium would be able to displace Z^{2+} ions.

15. **A**
The melting point generally increases from sodium to aluminium. Silicon has a high melting point as it has strong covalent bonds between atoms which require a large amount of energy to overcome. The melting points of phosphorus, sulfur, chlorine and argon are low as they have weak forces of attraction between molecules.

Option B is wrong. The size of the atom generally decreases across the period.

Option C is wrong. The number of electrons involved in bonding increases from sodium to silicon and decreases from silicon to argon.

Option D is wrong. Across the period, the size of cations are usually smaller than the size of anions. This is because atoms lose electrons to form cations but gain electrons to form anions. Hence, cations would have one less electron shell as compared to anions.

Chapter 12

Level 1

1. **B**
Rusting is only used to describe the corrosion of iron. The presence of sodium chloride speeds up the rate of rusting. Rusting causes iron metal to be lost in structure of steel, weakening it.

2. **B**
Recycling is not cheap as time and money is spent on transporting and sorting the scrap iron waste.

3. **D**
Copper and silver are below hydrogen in the reactivity series and hence would not react with dilute acids. Magnesium is less reactive than sodium while iron is less reactive than calcium.

Level 2

4. **A**
Calcium is more reactive than magnesium and hence will be able to displace magnesium from a solution of magnesium ions. Copper, iron and zinc are less reactive than magnesium and hence will not be able to displace magnesium from a solution of magnesium ions.

5. **D**
Metal **X** reacts slowly in cold water but vigorously with steam. This would mean that metal **X** is magnesium. Magnesium reacts with chlorine to form $MgCl_2$.

6. **A**
A more reactive metal would form a more stable compound. A more stable compound is less likely to thermally decompose when heated.

Calcium is the most reactive of all the metals listed. Hence, calcium carbonate would decompose the least for the same amount of time used to heat the carbonate. This is followed by zinc carbonate and iron(II) carbonate. Copper(II) carbonate is the least stable compound since copper is the least reactive metal. Hence, it will decompose the most.

7. **B**
Copper displaces X^+ ions from solution and hence copper is more reactive than metal **X**. Metal **Y** displaces Cu^{2+} ions from solution and hence metal **Y** is more reactive than copper. **X** cannot displace Y^{2+} ions from solution and hence, **X** is less reactive than **Y**. The order of reactivity of metals starting from the least reactive is **X**, Cu and **Y**.

8. **A**
Magnesium can displace all the listed ions except for Na^+ and Ca^{2+} since it is below sodium and calcium in the reactivity series. Zinc can only displace Cu^{2+}, Pb^{2+}, Fe^{2+} and Ag^+ since it is above copper, iron, lead and silver in the reactivity series.

Level 3

9. **B**
Statement 1 is true. Since silver is below hydrogen in the reactivity series, silver can be extracted using the experiment in Figure 12.3.

Statement 2 is not true. Copper is reduced since its oxidation state decreases from +2 in CuO to 0 in Cu. Hence, hydrogen is a reducing agent and not an oxidising agent.

Statement 3 is not true. Copper is below hydrogen in the reactivity series. Hence, it does not react with dilute hydrochloric acid to produce hydrogen gas needed for the reaction.

Statement 4 is true. Zinc is above hydrogen in the reactivity series. Hence, it reacts with dilute hydrochloric acid to produce hydrogen gas.

10. **C**
Silver is an unreactive metal and hence it cannot react with dilute nitric acid. Only zinc will react with nitric acid to form zinc nitrate and hydrogen in the equation below.

$Zn + 2HNO_3 \longrightarrow Zn(NO_3)_2 + H_2$

Hydrogen does not rekindle a glowing splint.

Number of moles of H_2 gas produced

$= \frac{48}{1000} \div 24 = 0.0200$ mol

From the equation, 1 mol of zinc produces 1 mol of hydrogen gas. Hence, 0.0200 mol of zinc would produce 0.0200 mol of hydrogen gas.

Mass of zinc present in alloy = $0.0200 \times 65 = 1.30$ g

Mass of silver present in alloy = $5 - 1.30 = 3.70$ g

Number of moles of acid present = $\frac{50}{1000} \times 1 = 0.0500$

From the equation, 2 mol of acid produce 1 mol of hydrogen gas. 0.400 mol of acid would produce 0.0200 mol of hydrogen gas.

Hence, the nitric acid is in excess and not all of the acid would react.

11. **B**
Metal **M** is likely to be iron since it rusts when exposed to air and water. It also reacts slowly with steam. Any solution containing iron(II) or iron(III) ions will form coloured precipitates when aqueous sodium hydroxide is added.

Statement 1 is true. Iron could form stainless steel, which is resistant to corrosion.

Statement 2 is not true. Iron is less reactive than magnesium and hence cannot displace magnesium from its solution.

Statement 3 is true. When iron reacts with oxygen in the air, two oxides of the formula FeO and Fe_2O_3 are formed.

Statement 4 is true. Tin acts as a protective layer that prevents iron from rusting.

12. **D**
Metal **J** displaced all the other metal ions from their solutions. Hence, metal **J** is the most reactive metal. Metal **H** displaced all other metal ions from their solutions, except for metal **J**. Hence, it is the second most reactive metal after metal **J**. Metal **I** displaced only metal **K** from its solution and hence metal **I** is the next most reactive metal followed by metal **K**. As such, option D best represents the metals since magnesium (**J**) is more reactive than zinc (**H**), which is more reactive than iron (**I**) and then copper (**K**). Potassium cannot be used as it will react explosively in water.

13. **D**
After a few days, the iron wire will react with all the oxygen gas in the gas jar to form rust. Hence, the colour of the iron wire changes from grey to red-brown. The cotton wool dries up since water is also required for iron to rust. As oxygen gas is used up in the gas jar, the total volume of gas present in the jar will decrease. This causes the water level to rise to fill up part of the gas jar. However, the water will not rise to fill up the whole gas jar since nitrogen gas is still present.

14. **D**
From the ionic equations, **G** is more reactive than **H**, while **K** is more reactive than **G**. **L** is the most reactive of the four metals since L^+ cannot be displaced by **K**.

Statement 1 is not true since **H** is less reactive than **K**, it is a weaker reducing agent than **K**.

Statement 2 is not true. **K** is more reactive than **H**. So, **K** cannot be magnesium since it is less reactive than calcium.

Statement 3 is not true. **L** cannot be silver since **L** is a very reactive metal.

Statement 4 is true. **L** is the most reactive metal followed by **K**, **G** and **H**.

Chapter 13

Level 1

1. **C**
Photosynthesis requires energy in the form of sunlight. Hence, it is endothermic.

2. **A**
Solid carbon dioxide sublimed to form gaseous carbon dioxide. The process would require energy to overcome the forces of attraction between particles in a solid to form a gas. Hence, energy is absorbed during the process.

3. **B**
In an exothermic reaction, energy is released when reactants are converted into products.

4. **B**
Energy is absorbed when forces of attraction between particles are overcome. This would allow particles to move further apart, resulting in a change of state. This change is a physical process and not a chemical change.

5. **D**
An exothermic reaction would result in a release of energy. This causes the temperature of the solution to increase.

6. **D**
A neutralisation reaction is an exothermic reaction which causes the temperature of the solution to increase. After the reaction has completed, the temperature of the solution decreases back to room temperature.

Level 2

7. **D**
Since the reactants are lower in energy level than the products, the energy level diagram represents that of an endothermic reaction. In an endothermic reaction, energy is absorbed. This causes the temperature of the resultant reaction mixture to decrease.

The burning of methane and the neutralisation reaction between hydrochloric acid and sodium hydroxide are exothermic reactions which release energy.

8. **B**
The dissolution of ammonium chloride is an endothermic process which absorbs energy. This causes the temperature of the solution to decrease. After some time, the temperature of the solution increases back to room temperature. Therefore, option B is correct.

Option C represents an exothermic reaction.

Options A and D are wrong as the temperature of the solution would increase to room temperature after all the ammonium chloride has dissolved.

9. **A**

Fuel	Number of Moles of Fuel in 10g / mol	Energy Produced When 10 g of Fuel Burnt / kJ/mol
W	$10 \div 16 = 0.625$	$891 \times 0.625 = 557$
X	$10 \div 28 = 0.357$	$283 \times 0.357 = 101$
Y	$10 \div 46 = 0.217$	$1367 \times 0.217 = 297$
Z	$10 \div 114 = 0.0877$	$5430 \times 0.0877 = 476$

10. **D**
An exothermic reaction releases energy, causing the temperature of the reaction mixture to increase. After some time, the reaction stops as the reactants are used up. As the temperature of the reaction mixture is higher than its surroundings, energy is lost to the surroundings. Hence, the temperature of the solution eventually falls back to room temperature.

11. **B**
Equation 1 represents a neutralisation reaction which is exothermic.

Equation 2 represents the combustion of hydrogen to form water which is also exothermic.

Equation 3 is a thermal decomposition reaction which is endothermic.

Level 3

12. **D**
The neutralisation reaction between hydrochloric acid and sodium chloride and the combustion of methane are exothermic reactions. The energy of the reactants in both options A and B will thus be higher than the energy of the products. This results in a negative ΔH value.

The decomposition of calcium carbonate and the dissolution of ammonium chloride in water are endothermic. The energy of the reactants in both options C and D will thus be lower than the energy of the products. This results in a positive ΔH value.

13. **B**
Statement 1 is correct. Since the highest recorded temperature corresponds to when 25 cm^3 of alkali is added, complete neutralisation occurred when 25 cm^3 of alkali was added.

Statement 2 is correct. Neutralisation is an exothermic reaction that causes the temperature of the solution to increase.

Statement 3 is correct.

$NaOH + HNO_3 \longrightarrow NaNO_3 + H_2O$

Number of moles of HNO_3 added

$= \frac{20}{1000} \times 1.0 = 0.0200$ mol

From equation, 1 mol of HNO_3 reacts with 1 mol of NaOH.

Number of moles of NaOH reacted = 0.0200 mol

Volume of NaOH required for complete reaction = 25 cm^3

Concentration of NaOH reacted

$= 0.0200 \div \frac{25}{1000} = 0.800$ mol/dm^3

Statement 4 is not correct. The highest temperature reached is when the volume of alkali added is 25 cm^3.

14. **A**
The definition of enthalpy change of formation involves the formation of 1 mol of H_2O. Since the reaction involves using elements, ions like H^+ and O^{2-} should not be included in the equation.

15. **B**
Statement 1 is true. The reaction is a displacement reaction since the more reactive calcium displaced the less reactive copper from its nitrate solution.

Therefore, the ionic equation is

$Ca(s) + Cu^{2+}(aq) \longrightarrow Cu(s) + Ca^{2+}(aq)$.

Statement 2 is not true. Since the beaker felt hot to the touch, the reaction is an exothermic reaction. Energy would be released instead.

Statement 3 and 4 are true. The temperature of the solution increases initially as energy is released from the reaction. After a few hours, the reaction is completed and no more energy is released. Hence, the temperature of the reaction mixture to decreases back to room temperature. The temperature-time graph could hence look like that in statement 4.

Chapter 14

Level 1

1. **B**
When the reaction mixture is immersed in an ice bath, its temperature decreases. As a result, the reactant particles have less kinetic energy and collide less frequently. The proportion of particles colliding with energy greater than or equal to the activation energy decreases. This decreases the frequency of effective collisions and hence decreases the rate of reaction.

2. **C**
The rate of the reaction can be determined by calculating the gradient of the graph. The rate of the reaction is the fastest at the beginning where the gradient of the graph is the steepest. Since copper(II) carbonate is in excess, it would still be present in the reaction mixture at **X** minutes. All the sulfuric acid would have reacted, and the reaction would have stopped at **X** minutes.

3. **C**
For a reaction to occur, reactant particles must collide effectively. Reactant particles must collide with energy that is greater than or equal to the activation energy.

4. **A**
An increase in the surface area of reactant particles will only affect reactions that involve solid reactants.

5. **D**
The gradient of the graph shows the rate of the reaction. The steeper the gradient, the faster the rate of reaction.

At t_1, the gradient of the curve is the steepest which represents the fastest reaction. As the reaction proceeds, the rate of reaction decreases until the reaction stops at t_4.

Hence, the order of rate of reaction:

$t_4 < t_3 < t_2 < t_1$

Level 2

6. **A**
Adding water into the reaction mixture decreases the concentration of hydrogen peroxide. Hence, the particles of hydrogen peroxide are further apart. This causes the frequency of effective collisions to decrease, causing a decrease in the rate of reaction.

Immersing the reaction mixture in a hot water bath and increasing the concentration of hydrogen peroxide would both increase the rate of reaction.

Decreasing the pressure of the reaction mixture does not affect the decomposition of hydrogen peroxide since there are no gaseous reactants.

7. **D**
$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$

The rate of reaction can be investigated by measuring the loss of the mass of the reactants or the increase in the volume of carbon dioxide gas against time. As most acid reactions are exothermic, the change in the temperature of the reaction mixture against time can also be measured.

8. **C**
Magnesium is more reactive than zinc. Hence, it will react faster with nitric acid. The same number of moles of hydrochloric acid and nitric acid dissociate in water to produce the same number of moles of H^+ ions. Hence, there is no change in the rate of reaction. Increasing the concentration of nitric acid would increase the number of reactant particles. This increases the frequency of effective collisions and hence increases the rate of the reaction.

9. **C**

$3H_2(g) + N_2(g) \longrightarrow 2NH_3(g)$

Since hydrogen and nitrogen exist as gases, an increase in pressure causes the particle spacing to decrease. Hence, the reactant particles collide more frequently and the rate of reaction increases.

An increase in temperature causes an increase in the kinetic energy of the particles. Hence, reactant particles collide more frequently and the rate of reaction increases. More particles have energy that is greater than or equal to the activation energy at higher temperatures. Hence, the frequency of effective collisions increases, causing the rate of reaction to increase.

The increase in surface area would not affect the reaction as there are no solid reactants.

Level 3

10. **D**

Comparing the data from experiments 1 and 2, when the concentration of **X** is doubled, the rate of reaction is doubled. Hence, doubling the concentration of **X** doubles the rate of reaction. Comparing the data from experiments 2 and 3, when the concentration of **Y** is doubled, the rate of reaction remains the same. Hence, doubling the concentration of **Y** will not affect the rate of reaction.

11. **B**

$H_2SO_4 + Mg \longrightarrow MgSO_4 + H_2$

$2HNO_3 + Mg \longrightarrow Mg(NO_3)_2 + H_2$

Number of moles of acid $= \frac{10}{1000} \times 1 = 0.01$ mol

Number of moles of Mg $= 6 \div 24 = 0.25$ mol

From the equation, 1 mol of Mg reacts with 1 mol of H_2SO_4 and 2 mol of HNO_3 respectively.

0.25 mol of Mg will react with 0.25 mol of H_2SO_4 and 0.125 mol of HNO_3 respectively. Hence, both H_2SO_4 and HNO_3 are the limiting reactants, and the number of moles of acid used up in the reaction is the same.

Number of moles of H_2 gas produced in experiment **I** = 0.01 mol

Number of moles of H_2 gas produced in experiment **II** = 0.005 mol

Hence, the volume of gas produced is different. H_2SO_4 ionises to produce twice as much H^+ ions as compared to HNO_3. Hence, the rate of reaction is faster in experiment **I** than in experiment **II**.

12. **C**

Since **E** has a steeper increase in temperature, it would suggest that the concentration of the reactants is higher in **E** than in **F**.

13. **C**

Statement 1 is not correct. Graph **G** has a steeper gradient than graph **I**. This signifies that it has a faster rate of reaction. Hence, experiment **G** was carried out at a higher temperature than experiment **I**.

Statement 2 is correct. Experiment **G** has a faster rate of reaction as compared to experiment **I**. Hence, the magnesium carbonate used in experiment **G** would have a larger surface area than in experiment **I**. The mass loss was the same since the magnesium carbonate used was in excess.

Statement 3 is correct. Since sulfuric acid was the limiting reactant, an increase in the number of moles of sulfuric acid would cause an increase in the mass loss of the reaction mixture. An increase in the concentration of sulfuric acid increases the frequency of effective collisions. This increased the rate of reaction, allowing graph **H** to have a steeper gradient than in graph **I**.

14. **D**

The lower the activation energy, the more spontaneous the reaction is. Since these reactions release heat, they are exothermic reactions. Hence, option D is correct as reaction 1 has a low activation energy and is an exothermic reaction whereas reaction 2 has a high activation energy and is an endothermic reaction.

15. **A**

$2HCl + FeCO_3 \longrightarrow FeCl_2 + CO_2 + H_2O$

$H_2SO_4 + FeCO_3 \longrightarrow FeSO_4 + CO_2 + H_2O$

Number of moles of acid $= \frac{20}{1000} \times 1 = 0.02$ mol

Number of moles of $FeCO_3 = 10 \div 116 = 0.0862$ mol

From the equation, 1 mol of $FeCO_3$ reacts with 2 mol of HCl and 1 mol of H_2SO_4 respectively. 0.0862 mol of $FeCO_3$ reacts with 0.1724 mol of HCl and 0.0862 mol of H_2SO_4 respectively. Hence, H_2SO_4 and HCl are the limiting reactants.

Number of moles of CO_2 gas produced in experiment **I** = 0.01 mol

Number of moles of CO_2 gas produced in experiment **II** = 0.02 mol

For the same concentration of acid, H_2SO_4 has twice the concentration of H^+ ions compared to HCl. Experiment **II** will thus have a faster rate of reaction and a steeper gradient than experiment **I**.

Revision Paper 2

1. **A**

Balanced chemical equation:

$K_2CO_3 + 2HNO_3 \longrightarrow 2KNO_3 + CO_2 + H_2O$

Ionic equation:

$2K^+ + CO_3^{2-} + 2H^+ + 2NO_3^- \longrightarrow 2K^+ + 2NO_3^- + CO_2 + H_2O$

$CO_3^{2-} + 2H^+ \longrightarrow CO_2 + H_2O$

2. **D**

M_r of oxide of iron $= 58 \div 0.25 = 232$

M_r of FeO $= 56 + 16 = 72$

M_r of $FeO_2 = 56 + (2 \times 16) = 88$

M_r of $Fe_2O_3 = (56 \times 2) + (3 \times 16) = 160$

M_r of $Fe_3O_4 = (56 \times 3) + (4 \times 16) = 232$

Hence, the iron oxide has a chemical formula of Fe_3O_4.

3. **B**

$2H_2 + O_2 \longrightarrow H_2O$

Number of moles of O_2 gas

$= \frac{4}{24} = 0.167$ mol

Number of moles of H_2 gas

$= \frac{1}{2} = 0.500$ mol

2 mol of hydrogen gas reacts with 1 mol of oxygen gas to produce 2 mol of water.

0.500 mol of hydrogen gas would hence require 0.250 mol of oxygen gas for complete reaction. Since only 0.167 mol of oxygen gas is present, it is the limiting reagent.

0.167 mol of oxygen would produce 0.333 mol of water.

Mass of water $= 0.333 \times 18 = 6.00$ g

4. **B**
$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$
At room temperature, water exists as a liquid. Hence, its gaseous volume of is 0 cm^3.
Mole ratio $CH_4 : O_2 = 1 : 2 = 10\ cm^3 : 20\ cm^3$
10 cm^3 of methane reacts with 20 cm^3 of oxygen. Since 50 cm^3 of oxygen is present, 30 cm^3 of oxygen is left over in the reaction. Since methane is the limiting reactant, all of it is used up in the reaction.
Mole ratio of $CH_4 : CO_2$
$= 1 : 1 = 10\ cm^3 : 10\ cm^3$
10 cm^3 of CO_2 is formed at the end of the reaction.

5. **A**
Hydrogen chloride gas is a covalent compound with no mobile ions to conduct electricity. A solution of hydrochloric acid contains ions. These ions can act as mobile charge carriers to conduct electricity. Both compounds are acidic. Hence, they will turn damp blue litmus paper red and will react with aqueous sodium hydroxide. Both compounds will not react with copper since copper is an unreactive metal.

6. **C**
Aluminium oxide is an amphoteric oxide while copper(II) oxide and magnesium oxide are basic oxides. All three oxides can react with carbon dioxide, which is an acidic oxide. Phosphorus(V) oxide is an acidic oxide and does not react with carbon dioxide.

7. **A**
Substance **C** would likely be an amphoteric oxide since it is able to react with both acids and alkalis. Hence, element **B** is likely a metal.
Statement 1 is correct as zinc oxide is amphoteric.
Statement 2 is correct. Element **B** could be lead, aluminium or zinc. These metals have a greater atomic mass as compared to magnesium.
Statement 3 is not correct as acidic oxides cannot react with acids.
Statement 4 is not correct. An amphoteric oxide reacts with acids to form a salt and water only.

8. **C**
Zinc oxide is an amphoteric oxide that can react with acids and alkalis. Phosphorus(V) oxide is an acidic oxide that can react with alkalis. Magnesium carbonate can react with acids while copper cannot react with any acids or alkalis.
Hence, an acid and an alkali can be added into the mixture to react will all the solids except for copper.

9. **B**
Statement 1 is correct.
$2CH_3COOH + Ca(OH)_2 \longrightarrow (CH_3COO)_2Ca + 2H_2O$
Number of moles of ethanoic acid
$= \frac{30}{1000} \times 1.0 = 0.0300\ mol$
Number of moles of calcium hydroxide
$= \frac{20}{1000} \times 1.0 = 0.0200\ mol$
1 mol of calcium hydroxide reacts with 2 mol of ethanoic acid.
0.0200 mol of calcium hydroxide will require 0.0400 mol of ethanoic acid for complete reaction.
Since only 0.0300 mol of ethanoic acid is present, it is the limiting reactant.
Statement 2 is not correct. Since calcium hydroxide is in excess, the pH of the resultant mixture is greater than 7.
Statement 3 is not correct. The correct chemical formula of calcium ethanoate is $(CH_3COO)_2Ca$.
Statement 4 is correct. Since calcium hydroxide is in excess, a white precipitate is observed when carbon dioxide is bubbled into the reaction mixture.

10. **B**
Ammonium ions react with hydroxide ions to form ammonia gas and water.

11. **A**
Copper(II) ions react with aqueous ammonia to form a light blue precipitate that dissolves in excess aqueous ammonia to form a dark blue solution. Iron(II) and iron(III) ions do not dissolve in excess aqueous ammonia. Potassium ions do not form a precipitate with aqueous ammonia. Potassium salts are also colourless.

12. **B**
Magnesium carbonate reacts with nitric acid to produce effervescence, which allows it to be distinguished from the other two substances. Test 3 is a test for nitrate ions. This allows sodium nitrate to be distinguished from zinc chloride.

13. **D**
Four oxygen atoms must be present with in order for the chlorate(VII) ion to have an overall charge of –1. Hence, the formula of manganese(IV) chlorate(VII) would be $Mn(ClO_4)_4$.

14. **B**
Oxidation state of Mn:
MnO_2: +4
MnO: +2
MnO_2^{2+}: +6
MnO_4^-: +7
Mn: 0

15. **C**
Bromine is below chlorine in the periodic table. Hence, it is less reactive than chloride and will not displace chlorine from sodium chloride. Astatine is at the bottom of Group 17. Since the melting and boiling points of elements increase down the group, astatine exists as a solid. Chlorine is above iodine in the periodic table. Hence, it is more reactive than iodine and will displace iodine from sodium iodide. The iodine produced will dissolve in solution, turning it brown.

16. **B**
Going down Groups 1 and 2, the reactivity of elements increases while the melting and boiling point decreases. Going down Groups 16 and 17, the reactivity of elements decreases while the melting and boiling points increases.

17. **C**
W exists as a yellow solid that is a poor conductor of electricity. This indicates that **W** could be sulfur in Group 16. **X** is a grey solid with low melting point and density. It is likely to be a Group 1 metal. **Y** is a red-brown liquid that cannot conduct electricity. It is likely to be bromine, which is a Group 17 element.

18. **B**
Option A is a neutralisation reaction while option C is an acid-metal reaction.
Option D is a displacement reaction where chlorine displaces the less reactive iodine from its halide solution. Only option B is unlikely to occur as copper is less reactive than zinc and hence would not be able to displace zinc from its salt solution.

19. **D**
Metals form compounds by losing electrons to form cations. Since magnesium is more reactive than iron it will lose electrons to form compounds more readily.

20. **B**

$\mathbf{R} + 2HCl \longrightarrow \mathbf{R}Cl_2 + H_2$

Number of moles of acid reacted

$= \frac{40}{1000} \times 1 = 0.0400$ mol

2 mol of acid reacts with 1 mol of **R**.

0.0400 mol of acid would react with 0.0200 mol of **R**

M_r of **R** = 1.3 ÷ 0.0200 = 65

Metal **R** is zinc.

Option A is not true. Iron is less reactive than zinc and hence cannot displace zinc from its salt solution.

Option B is true. Zinc does not react with cold water but reacts readily with steam.

Option C is not true. Zinc reacts with oxygen to form only one oxide, zinc oxide, ZnO.

Option D is not true. Zinc chloride solution is colourless.

21. **B**

The temperature of the solution initially decreased due to the dissolution of ammonium chloride, which is endothermic. After which, the temperature of the solution increased due to the reaction between ammonium chloride and aqueous sodium hydroxide, which is exothermic. Ammonium salts react with alkalis to produce ammonia gas which turns damp red litmus paper blue. The rate of reaction does not increase as the reaction proceeds since the concentration of the reactants decreases as they form products.

22. **D**

The acid is the limiting reactant.

Condition 1 will not produce **X**. Decreasing the concentration of the acid by half decreases the rate of reaction. The total volume of gases produced will also be halved.

Condition 2 will not produce **X**. Both acids will have the same rate of reaction as they have the same concentration.

Condition 3 will produce **X**. Introducing additional nitric acid, which is the limiting reactant, would increase the volume of gas produced.

Since a lower concentration of nitric acid is introduced, the overall concentration of nitric acid in the reaction decreases. This decreases the rate of reaction.

Condition 4 will produce **X**. The number of moles of acid in condition 4 is greater than that in **Y**. Hence, more gas is produced. The concentration in condition 4 is lower than that in **Y**. Hence, the rate of reaction in condition 4 would be slower.

23. **B**

Statement 1 is correct. Neutralisation is an exothermic reaction and hence energy will be released during the reaction.

Statement 2 is not correct. Increasing the pressure of the reaction mixture would not speed up the reaction since there are no gaseous reactants.

Statement 3 is correct.

$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$

Number of moles of H_2SO_4

$= \frac{20}{1000} \times 0.8 = 0.0160$ mol

Number of moles of NaOH

$= \frac{30}{1000} \times 1.0 = 0.0300$ mol

2 mol of sodium hydroxide would react with 1 mol of sulfuric acid.

0.0300 mol of sodium hydroxide would react with 0.0150 mol of sulfuric acid.

Number of moles of unreacted sulfuric acid

= 0.0160 – 0.0150 = 0.00100 mol

Total volume of solution

$= \frac{(20 + 30)}{1000} = 0.0500$ dm^3

Concentration of unreacted sulfuric acid

$= \frac{0.00100}{0.0500} = 0.0200$ mol/dm^3

Statement 4 is correct. The progress of the reaction can be followed using a thermometer since complete neutralisation occurs when the most amount of energy is released. This would correspond to the highest increase in temperature.

24. **B**

As the reaction proceeds, the concentration of the reactants decreases while the concentration of the products increases. Since **W** and **X** are decreasing in concentration, they are the reactants. Since **Y** and **Z** are increasing in concentration, they are the products. During the reaction, 4 units of **W** and 2 units of **X** are converted to 3 units of **Y** and 2 units of **Z**. So, the equation will be $4\mathbf{W} + 2\mathbf{X} \longrightarrow 3\mathbf{Y} + 2\mathbf{Z}$.

25. **C**

II has a faster rate of reaction than **I** as **II** has a steeper initial gradient than **I**. However, the reaction in **II** produces less volume of gas compared to the reaction in **I**.

Option A: Decreasing the surface area of calcium carbonate will cause the reaction in **II** to be slower than in **I**.

Option B: The concentration of the hydrogen ions is the same for both reactions. Hence, they will have the same rate of reaction and the initial gradient of the graphs obtained would be the same.

Option C: Sulfuric acid is a dibasic acid whereas nitric acid is a monobasic acid. Hence, sulfuric acid contains twice the amount of hydrogen ions per mol of acid as compared to nitric acid. Therefore, the reaction involving sulfuric acid is faster. However, since calcium sulfate is insoluble, it coats the calcium carbonate. This prevents further reaction from occurring. Hence, only a small amount of carbon dioxide is produced before the reaction stops.

Option D: The type of acids used is the opposite of what was used in option C. Hence, experiment **I** will produce graph **II** whereas experiment **II** will produce graph **I** instead.

Chapter 15

Level 1

1. **B**

A mixture would melt or boil over a range of temperatures. Since the fractions collected are mixtures, they are collected over a range of temperatures.

2. **A**

Bioethanol is a renewable resource as it can be processed from plants or animals and can be replaced after use.

3. **A**

In the fractional distillation of petroleum, petroleum is heated. Petroleum vapour is then passed into the fractionating column where they condense according to their different fractions. Hence, the different fractions are separated according to their boiling points.

4. **A**
Bioethanol is a renewable alternative resource that is obtained from plants. Fuels release energy when burnt to power machines like vehicles. They do not require a lot of energy to burn.

Level 2

5. **D**
Hydrogen is obtained from cracking of hydrocarbons in petroleum while bioethanol is obtained from plants. Hydrogen burns in oxygen to form water only while bioethanol burns in oxygen to produce carbon dioxide, which is an acidic gas, and water.

6. **A**
The reaction in option A produces hydrogen which is not a product of the combustion of hydrocarbons.

7. **B**
Both fuels are obtained from living matter. Hence, they are both biodegradable. Since vehicles running on biodiesel can travel a longer distance, biodiesel produces more energy when burnt.

8. **C**
Molecules obtained at a higher fraction contain less carbon and hydrogen atoms and are also smaller in size. Only molecules belonging to the topmost fraction exist as gases.

9. **C**
$2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$
Number of moles of C_8H_{18} burnt
$= \frac{200}{12 \times 8 + 18} = 1.75$ mol
Mole ratio of $C_8H_{18} : CO_2 : H_2O$
$= 2 : 16 : 18 = 1.75 : 14.00 : 15.75$
Total moles of gases produced
$= 14.0 + 15.75 = 29.75$ mol
Total volume of gases produced
$= 29.75 \times 24 = 714$ dm^3

Level 3

10. **A**
Number of moles of C_2H_6 in 10 g
$= 10 \div 30 = 0.333$ mol
Energy produced by 0.333 mol of C_2H_6
$= 0.333 \times 1400 = 466$ kJ
Number of moles of CH_4 in 10 g
$= 10 \div 16 = 0.625$ mol
Energy produced by 0.625 mol of CH_4
$= 0.625 \times 890 = 556$ kJ
Number of moles of H_2 in 10 g
$= 10 \div 2 = 5.00$ mol
Energy produced by 5.00 mol of H_2
$= 5.00 \times 286 = 1430$ kJ
Hence, 10 g of H_2 produces the most energy, followed by 10 g of CH_4 and 10 g of C_2H_6.

11. **D**
Statement 1 is not correct. Hydrocarbons in fraction **X** have a lower boiling point compared to hydrocarbons in fraction **Y**. Hence, hydrocarbons in fraction **X** evaporate more easily and are thus more volatile.

Statement 2 is not correct. The range of boiling points of fractions **X** and **Y** is different as the size of molecules are different. It would also be impossible to separate two fractions with the same range of boiling points using fractional distillation.

Statement 3 is correct. Each fraction would contain hydrocarbons with different numbers of carbon atoms. A hydrocarbon with a boiling point that is in between the range of boiling points of two fractions can exist in both fractions.

Statement 4 is correct. Hydrocarbons from a lower fraction are larger and have longer carbon chains. Hence, the average molar mass of molecules in fraction **Y** will be greater than that of fraction **X**.

12. **C**
The following are the energy produced when 1 g of each fuel is burnt.
Fuel **E** $= \frac{1}{282 \times 7153} = 25.4$ kJ
Fuel **F** $= \frac{1}{114 \times 5430} = 47.6$ kJ
Fuel **G** $= \frac{1}{366 \times 6700} = 18.3$ kJ

13. **C**
$N_2H_4 + 3O_2 \longrightarrow 2NO_2 + 2H_2O$
Hence, oxide **A** is NO_2 and oxide **B** is H_2O.
Option C is not true. Fuels must release energy when burnt. Therefore, burning hydrazine should be exothermic, not endothermic.

14. **B**
Plants absorb carbon dioxide during photosynthesis. This offsets the carbon dioxide that is produced when the biofuels are burnt.

Chapter 16

Level 1

1. **B**
Molecules from the same homologous series have the same general formula.

2. **B**
Ethene will react with chlorine rapidly while ethane will react with chlorine in the presence of ultraviolet (UV) light. Hence, a reaction will occur with both ethane and ethene.

3. **C**
Down the homologous series, the size of the molecules increases. Hence, the melting and boiling points, as well as the density of the alkanes increase. Most organic molecules are colourless. Molecules in the same homologous series have similar chemical properties.

4. **A**
Alkenes are unsaturated hydrocarbons as they contain carbon–carbon double bonds.

Level 2

5. **D**
Addition reactions do not form acidic products. Cracking can form alkanes, alkenes and hydrogen gas, which are not acidic. Neutralisation reactions produce neutral products. Substitution reactions involve the formation of an acidic gas like hydrogen chloride.

6. **D**
Incomplete combustion of hydrocarbons usually produces carbon monoxide.
Balanced chemical equation:
$2C_3H_8 + 7O_2 \longrightarrow 6CO + 8H_2O$

7. **B**
Each successive molecule in a homologous series differs by a $-CH_2-$ unit in its molecular formula. If the third member of the alkynes homologous series is C_4H_6, the second member would be C_3H_4 and the first member would be C_2H_2.

8. **C**
Cracking involves the breaking down of a large alkane molecule. Options B and D are alkenes and CH_2 in option D is not a stable molecule.

Level 3

9. **D**
The hydrocarbon can react with 2 mol (48 dm^3) of hydrogen gas to form C_4H_{10}.
Most hydrocarbons can burn in air.
A saturated hydrocarbon with four carbon atoms has the formula C_4H_{10}. An unsaturated hydrocarbon with the formula C_4H_6 has 4 less hydrogen atoms. Hence, 2 carbon–carbon double bonds are present in the structure. Since it has 2 carbon–carbon double bonds, 1 mol of the hydrocarbon would require 2 mol of chlorine to form a saturated compound with the formula $C_4H_6Cl_2$.

10. **D**
As the molecular mass of each substance is different, the mass of 1 mol of each substance is different. Ethane will not decolourise brown aqueous bromine in the dark whereas ethene will decolourise brown aqueous bromine rapidly. Ethane reacts with 1 mol of chlorine to form C_2H_5Cl whereas ethene reacts with 1 mol of chlorine to form $C_2H_4Cl_2$. 1 mol of a gaseous substance would occupy 24 dm^3.

11. **C**
The reaction is the hydrogenation of alkene **Q** to form alkane **R**. Only **Q** will be able to decolourise aqueous bromine in the dark. If **Q** is ethene, ethane is formed instead of propane. Alkene **Q** is unsaturated whereas alkane **R** is saturated.

12. **B**
The reaction involves substituting one hydrogen atom with a bromine atom. Hence, it is a substitution reaction between the alkane, C_nH_m, and bromine, which requires UV light. The product formed is colourless. C_2H_4 is an alkene which will react with bromine to form $C_2H_4Br_2$.

13. **A**
1 mol of substance **E** undergoes combustion to form 2 mol of carbon dioxide and 3 mol of water. Hence, 1 molecule of **E** would contain 2 carbon atoms and 6 hydrogen atoms. **E** is thus ethane with the formula C_2H_6. **E** is formed when **D** reacts with hydrogen in an addition reaction. Hence, **D** is an alkene with 2 carbon atoms, which is ethene, C_2H_4. **E** reacts with chlorine in a substitution reaction to form C_2H_5Cl.

14. **A**
Option A is true. If hydrocarbon **E** is propane, it can undergo cracking to form ethene and methane. The equation will be $C_3H_8 \longrightarrow C_2H_4 + CH_4$.
Option B is not true. If hydrocarbon **F** is ethene and hydrocarbon **G** is propane, hydrocarbon **E** should have 5 carbon atoms.
Option C is not true. If hydrocarbon **F** is ethane, hydrocarbon **G** must be an alkene. Alkenes decolourise aqueous bromine in the dark.
Option D is not true. If hydrocarbon **G** is propane, hydrocarbon **F** must be an alkene and hydrocarbon **E** must be an alkane. Hence, only hydrocarbon **F** can decolourise aqueous bromine in the dark.

15. **B**
The hydrocarbon with the formula C_6H_{12} corresponds to the alkene general formula of C_nH_{2n}.
Hence, it can react with bromine to form the product, $C_6H_{12}Br_2$.
It can also react with hydrogen and a nickel catalyst to form C_6H_{14}.
It can also burn in air to form CO_2.
Since the hydrocarbon is an alkene, It will not be able to undergo cracking to form C_3H_6

Chapter 17

Level 1

1. **D**
All alcohols must have the hydroxyl (–OH) group in their structures.

2. **B**
Molecular formula of ethanol: C_2H_6O
Molecular formula of ethanoic acid: $C_2H_4O_2$

3. **C**
Options A and B are both ethanoic acid.
Option C is the chemical formula for ethanol.
Option D is the chemical formula for propanoic acid.

4. **A**
Carboxylic acids contain the carboxyl (–COOH) functional group in their structures. Options B and D do not have the carboxyl functional group.
Option C is methanoic acid.

5. **B**
When exposed in air for a prolonged period of time,the ethanol in wine is oxidised by the oxygen in the air to form ethanoic acid. Ethanoic acid is sour and is commonly known as vinegar.

6. **B**
The burning of propanol in oxygen is a combustion reaction which produces carbon dioxide and water.
The fermentation of glucose to form ethanol will produce carbon dioxide as a by-product.
The oxidation of ethanol would form ethanoic acid and water. No carbon dioxide is produced.

Level 2

7. **A**
Acidified potassium manganate(VII) will oxidise ethanol to ethanoic acid. In the process, the purple acidified potassium managanate(VII) decolourises.
Aqueous bromine is unable to react with the alcohol due to the absence of carbon–carbon double bonds.
Oxygen oxidises ethanol but does not produce an observation.
Alcohols are considered to be neutral and hence will not change the colour of Universal Indicator solution.

8. **A**
Option A is true. Alcohol **A**, which is ethanol, will oxidise to form ethanoic acid, which is in the same homologous series as carboxylic acid **B**.

Option B is not true. Alcohols do not react with alkanes to form carboxylic acids. Alcohols react with oxidising agents like oxygen or acidified potassium manganate(VII) to form carboxylic acids.

Option C is not true. Carboxylic acids do not undergo cracking.

Option D is not true. Alcohol **A** has two carbon atoms in its structure. So, it will oxidise to form a carboxylic acid with two carbon atoms. Carboxylic acid **B** contains three carbon atoms.

9. **C**
Purple acidified potassium manganate(VII) oxidises propanol but not propanoic acid. Damp blue litmus paper will turn red with propanoic acid but not with propanol. Damp red litmus paper remains unchanged with propanoic acid and propanol. Sodium carbonate will produce effervescence when reacted with propanoic acid but not with propanol.

10. **C**
Option A is not true. The glucose used for fermentation usually comes from plants.

Option B is true. Carbon dioxide is produced from the fermentation reaction. Carbon dioxide produces a white precipitate when bubbled into limewater.

Option C is not true. High temperatures will cause yeast, which is an enzyme, to denature. This will cause the fermentation reaction to stop. Fermentation occurs most efficiently at body temperature.

Option D is not true. Fermentation only produces ethanol. It cannot produce any other alcohols.

Level 3

11. **B**
The general formula of carboxylic acids is $C_nH_{2n+1}COOH$. When n = 20, the formula of the saturated acid is $C_{20}H_{41}COOH$. In order for the acid to react with chlorine gas without ultraviolet (UV) light, the molecule must contain carbon–carbon double bonds. For every carbon–carbon double bond, the molecule would have 2 less hydrogen atoms. Since 1 mol of the carboxylic acid reacts with 3 mol of chlorine, there are 3 carbon–carbon double bonds. Hence, the formula of the carboxylic acid is $C_{20}H_{35}COOH$.

12. **B**
Statement 1 is true. The presence of a carbon–carbon double bond allows **Q** to react with aqueous iodine.

Statement 2 is not true. The carboxyl (–COOH) group in **Q** can react with magnesium carbonate.

Statement 3 is true. The presence of the carbon–carbon double bond allows **Q** to react with hydrogen to form a saturated acid.

Statement 4 is true. Since there is a carbon–carbon double bond present, the molecule can be termed as an unsaturated carboxylic acid.

13. **A**
Burning 1 mol of **D**, which is an alcohol, produces 2 mol of carbon dioxide and 3 mol of water. Hence, the alcohol would contain 2 carbon atoms. Thus, **D** is ethanol.

Ethanol can be oxidised to ethanoic acid, which is **E**. Ethanoic acid is then reacted with sodium hydroxide to form **F** which is sodium ethanoate.

14. **B**
Statement 1 is true.

$2C_3H_7OH + 9O_2 \longrightarrow 6CO_2 + 8H_2O$

Mole ratio $C_3H_7OH : CO_2 = 2 : 6$

1 mol of C_3H_7OH produces 3 mol of CO_2.

$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$

Mole ratio $C_2H_5OH : CO_2 = 1 : 2$

1 mol of C_2H_5OH produces 2 mol of CO_2.

Hence, 1 mol of propanol will produce a greater volume of carbon dioxide.

Statement 2 is not true. Only ethanol can be obtained by fermentation of glucose in the presence of yeast.

Statement 3 is not true. Since ethanol has a lower molecular mass than propanol, it is a smaller molecule.

Statement 4 is true.

Chemical formula of propanol: C_3H_7OH

Chemical formula of ethanol: C_2H_5OH

15. **B**
When exposed to oxygen for a prolonged period of time, both the hydroxyl (–OH) groups will be oxidised. Hence, the correct structure of the carboxylic acid formed would be that of option B.

Option A shows that only one of the hydroxyl groups was oxidised.

Option C shows propane, which is not produced from the oxidation of the alcohol.

Option D is the structure of propanoic acid which only has one carboxyl (–COOH) functional group.

Chapter 18

Level 1

1. **D**
Option A shows the structure of ethene.

Option B shows the structure of a repeat unit of poly(ethene).

Option C shows the structure of ethane.

Option D shows the structure of poly(ethene).

2. **C**
Disposing of plastics in recycling bins prevents rubbish from piling up as plastics are sent for recycling. Thus, this is not an environmental issue.

The toxic gases produced from the burning of plastics can cause air pollution.

Plastics do not decompose. Thus, the plastic waste built up in landfills can cause land pollution.

Marine animals may swallow and choke on plastics that are disposed of into the sea.

3. **A**
Statement 1 is correct. A catalyst is used to speed up the cracking of poly(ethene).

Statement 2 is not correct. Combustion of poly(ethene) is not a chemical method of recycling poly(ethene).

Statement 3 is correct. Cracking produces smaller alkanes and alkenes which can be used in many other applications.

Statement 4 is not correct. Recycling plastics usually involves manpower required to transport, sort and clean the materials, which incur costs.

4. **A**
Converting plastics into pellets is a physical method of recycling plastics. The steps include sorting, washing, grinding and melting. Cracking is a chemical method of recycling plastics.

Level 2

5. **C**
Option A is correct. Addition polymerisation involve alkenes breaking their carbon–carbon double bonds and joining together without forming any by-products.

Option B is correct. Monomers used for addition polymerisation contain either a carbon–carbon double bond or a carbon–carbon triple bond.

Option C is not correct. Different alkene monomers can join together to form an addition polymer since they contain the carbon–carbon double bond which can break to form new single bonds.

Option D is correct. There is no loss of mass during addition polymerisation. Thus, the molecular mass of the polymer is equal to the molecular mass of the monomers that make up the polymer.

6. **A**
Options A and B have the molecular formula of an alkene, but only option A contains chlorine. Options C and D are saturated compounds that do not contain carbon–carbon double bonds.

7. **A**
Option B shows the structure of propene.

Option C shows the structure of a repeat unit that looks like polyethene.

Option D shows the structure of poly(propene).

Option A shows the structure of a repeat unit of poly(propene). The structure of a repeat unit does not require brackets like the structure of the polymer.

8. **A**
Option A is not an issue of recycling plastics. Educating the public on recycling plastics helps to address the issue of the public not knowing how to recycle plastics properly.

Option B is an issue if recycling bins are not available for the public to dispose of their plastic waste.

Option C is an economic issue as the use of manpower involves costs incurred.

Option D is an environmental issue as discharging untreated wastewater into water bodies causes water pollution.

Level 3

9. **D**
Option A is true. Cracking is a chemical method used to break down polymers. This is a way of recycling substance **F**.

Option B is true. Substance **F** is likely to be made into plastics. usually involves manpower required to transport, sort and clean the materials, which may thus incur high costs.

Option C is true. Since substance **F** is likely to be saturated, it will be able to undergo substitution with chlorine in the presence of ultraviolet (UV) light.

Option D is not true. Since substance **F** did not react with chlorine gas, this shows that it does not possess carbon–carbon double bonds. Thus, it would not be able to react with hydrogen in the presence of a nickel catalyst.

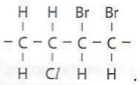
10. **B**
Option B is not an issue of recycling plastics as recycling plastic waste produces fuels for generating electricity which is useful.

Option A is an environmental issue caused by excessive use of plastics. The burning of plastics as a method of disposal causes harmful gases like carbon monoxide to be released into the environment.

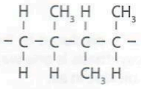
Option C is an economic issue. As the processes involved in recycling plastics require manpower, machinery and energy, the cost incurred can be high.

Option D is an economic issue. When the demand for recycled plastics in the market is low, the cost of recycling plastic waste is likely to be high.

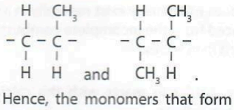
11. **D**
The carbon–carbon double bonds of both alkenes break during addition polymerisation and the monomers form single bonds with each other to form a repeat unit of



12. **B**
The structure shows an addition polymer with the repeat unit



which is made up of



Hence, the monomers that form the addition polymer are the two repeat units with their carbon–carbon single bonds converted into carbon–carbon double bonds. They are propene and butene.

13. **D**
Statement 1 is not true. Polymer **Q** contains a longer carbon chain than propane which contains only three carbon atoms. Thus, the combustion of polymer **Q** is likely to produce more pollutants such as carbon monoxide than the combustion of the same amount of propane.

Statement 2 is not true. Hydrocarbons that undergo cracking are usually saturated.

Statement 3 is not true. Polymer **Q** is likely to be a large molecule containing thousands or millions of atoms. C_8H_{18} is the chemical formula of an alkane containing 8 carbon atoms.

14. **B**
Structure 1 is formed when compound **Z** undergoes addition polymerisation through the breaking of the second carbon–carbon double bond in its carbon chain.

Structure 2 is not formed when polymer **Z** undergoes addition polymerisation.

Structure 3 is formed when compound **Z** undergoes addition polymerisation through the breaking of the first carbon–carbon double bond in its carbon chain.

15. **C**
Statement 1 is incorrect. The structure of the polymer does not contain a carbon–carbon double bond. Thus, it is not an unsaturated molecule.

Statement 2 is correct as the structure of the polymer shows that it is formed from two different monomers.

Statement 3 is incorrect as ethene forms the repeat unit below, which is not present in the structure of the polymer.

Statement 4 is correct. One of the alkene monomers, propene, contains a carbon–carbon double bond. Thus, it reacts with hydrogen in the presence of a nickel catalyst to form propane.

Chapter 19

Level 1

1. **A**
Carbon monoxide can be produced from the incomplete combustion of carbon-based fuels in car engines. Carbon monoxide binds irreversibly with the haemoglobin in red blood cells, lowering their ability to transport oxygen throughout the body.

2. **C**
In the carbon cycle, carbon dioxide is produced by living things through respiration. Photosynthesis is one way of regulating the amount of carbon dioxide in air.

3. **C**
Carbon monoxide does not usually exist naturally in air. It is a pollutant produced from the incomplete combustion of carbon-based fuels in vehicles.

4. **B**
Statement 1 is true. Acid rain reacts with the calcium carbonate present in buildings.

Statement 2 is not true. Acid rain decreases the pH of soil.

Statement 3 is true. Nitrogen oxides are produced due to the high temperatures of combustion engines while sulfur dioxide is produced from the combustion of petroleum in industries.

5. **B**
Statement 1 is true. Methane and carbon dioxide are waste gases produced by cows.

Statement 2 is not true. Both gases do not cause acid rain.

Statement 3 is not true. Limited oxygen would indicate that methane undergoes incomplete combustion, which mainly forms carbon monoxide.

Statement 4 is true. Both methane and carbon dioxide are greenhouse gases.

Level 2

6. **A**
Gas **J** is a greenhouse gas so it can be either carbon dioxide or methane. Methane does not react with carbon while carbon dioxide can react with carbon to form carbon monoxide.

7. **B**
Sulfur dioxide is a reducing agent that can be identified by bubbling the gas into a solution of acidified potassium manganate(VII). The purple solution would decolourise.

8. **A**
Industrial areas produce acidic gases like sulfur dioxide when they burn fossil fuels. These acidic gases combine with water vapour in clouds to form acid rain. The acid rain reacts with metals readily, corroding them quickly.

9. **B**
Carbon dioxide is a greenhouse gas that causes global warming. Global warming causes an increase in the likelihood of heat stroke and flooding of low-lying areas. It may also cause climate change, leading to less rainfall in rain-scarce areas.

Carbon dioxide does not form acid rain. Hence, an increased amount of carbon dioxide does not increase the frequency of acid rain.

Level 3

10. **C**
Calcium oxide is a basic oxide. So, it will be able to neutralise acidic gases present in the air.

It can react with carbon dioxide to form calcium carbonate. It can react with nitrogen dioxide to form calcium nitrate. It can also react with sulfur dioxide to form calcium sulfite. Calcium nitride cannot be formed from neutralisation reactions involving calcium oxide.

11. **C**
Gas **X** is oxygen as hydrogen peroxide decomposes to form oxygen and water. As air is present in the reaction flask, nitrogen would be the main impurity that would be collected with oxygen.

12. **C**
Option A is correct. When the frequency of complete combustion increases, less carbon monoxide is produced. Hence, less nitrogen dioxide is removed.

Option B is correct. A catalytic converter removes nitrogen oxides which cause acid rain.

Option C is not correct. Carbon dioxide, which is a greenhouse gas, is produced in catalytic converters. Hence, catalytic converters do not prevent global warming.

Option D is correct. According to the equation, catalytic converters remove harmful pollutants by converting them into less harmful gases before they are released into the atmosphere. Carbon monoxide causes breathing difficulties while nitrogen oxides cause acid rain.

13. **C**
Statement 1 is not true. When the volume of oxygen in the engine increases, the volume of carbon monoxide decreases while the volume of nitrogen oxides increases.

An increase in the volume of oxygen gas increases the temperature of the engine. This is because the probability of complete combustion of the fuel increases as the volume of oxygen gas increases. As more complete combustion occurs, more energy is being released into the engine.

Statement 2 is true. When the volume of oxygen increases, the volume of nitrogen oxides produced increases.

Statement 3 is true. When the temperature of the engine is low, more incomplete combustion occurs. This causes an increase in the volume of carbon monoxide formed.

Statement 4 is true. When the volume of oxygen gas increases, the volume of carbon monoxide produced decreases.

14. **C**
Zinc reacts with oxygen in air to form zinc oxide. This removes all the oxygen from the sample of air. Since 250 cm^3 of air is present, 21 % of this volume of air would contain oxygen.

Volume of oxygen removed

$= 250 \times \frac{21}{100} = 52.5\ cm^3$

Hence, volume of air left after the reaction

$= 250 - 52.5 = 197.5\ cm^3$

15. **C**
Biodiesel is produced from plants, which makes it biodegradable. It is a carbon neutral fuel since the carbon dioxide produced from its combustion can be taken in by plants during photosynthesis, causing the amount of carbon dioxide to remain unchanged. Plants are living things so they would respire to produce carbon dioxide. They do not only take in carbon dioxide, but also take in other substances like oxygen. Vegetable oil is a saturated compound that can be broken down by cracking into smaller molecules like biodiesel.

Revision Paper 3

1. **A**
When fossil fuels are burnt, air pollutants such as sulfur dioxide, nitrogen oxides, carbon monoxide and carbon dioxide are produced.

Option A is not true. Chlorofluorocarbons are not produced. Hence, the air pollutants produced from the burning of fossil fuels do not damage the ozone layer.

Options B and C are true. Sulfur dioxide and nitrogen oxides contribute to acid rain. Acids might corrode and irritate the skin.

Option D is true. Carbon dioxide is a greenhouse gas that contributes to global warming.

2. **C**
All other equations are balanced except for option C.

3. **C**
Petroleum is a finite resource that is formed from organic dead matter. It takes a long time for petroleum to be replenished. Bioethanol can be obtained from plants, which are renewable resources. Fuels obtained from plants are considered carbon-neutral fuels.

Both bioethanol and gasoline contain carbon and hydrogen atoms. Hence, they produce carbon dioxide and water when completely combusted.

4. **D**
Process C is photosynthesis and not respiration. Respiration produces carbon dioxide.

5. **C**
Alkanes do not decolourise aqueous bromine. Alkanes have the general formula C_nH_{2n+2}.

6. **A**
Alkanes react with halogens in the presence of ultraviolet (UV) light to form two products. For example, ethane, C_2H_6, reacts with chlorine to form C_2H_5Cl and HCl.

Alkenes react with halogens to form only one product. For example, ethene reacts with chorine to form $C_2H_4Cl_2$ only.

Hence, options B and D are wrong. Option A is correct as the molecular mass of the molecule is 44.

7. **B**
Each subsequent member of the homologous series differs in its molecular formula by a $-CH_2-$ unit. Since the third member of the series has a chemical formula of C_4H_8O, the second member would have a formula of C_3H_6O. The first member would have a formula of C_2H_4O.

8. **C**
Option A is not true. Ethane reacts with chlorine to form C_2H_5Cl but ethene reacts with chlorine to form $C_2H_4Cl_2$.

Option B is not true. Ethane reacts with bromine only in the presence of UV light. Ethene does not require any conditions to react with bromine.

Option C is true. Cracking ethane will allow ethene to be formed, with hydrogen as the by-product.

Option D is not true. Ethane cannot undergo a substitution reaction to form ethene. A carbon–carbon double bond cannot be formed from substitution reactions.

9. **B**
Number of moles of hydrogen reacted with **A** = 0 mol

Hence, vegetable oil **A** has no carbon–carbon double bonds and is saturated.

Number of moles of hydrogen reacted with **B**

$= 24 \div 24 = 1$ mol

Mole ratio of **B** : $H_2 = 1 : 1$

Hence, vegetable oil **B** has one carbon–carbon double bond.

Number of moles of hydrogen reacted with **C**

$= 48 \div 24 = 2$ mol

Mole ratio of **C** : $H_2 = 1 : 2$

Hence, vegetable oil **C** has two carbon–carbon double bonds.

Number of moles of hydrogen reacted with **D**

$= 96 \div 24 = 4$ mol

Mole ratio of D : $H_2 = 1 : 4$

Hence, vegetable oil **D** has four carbon–carbon double bonds.

10. **C**
Since both the chlorine atoms are added into the molecule, the reaction of **L** with chlorine is an addition reaction. Hence, **L** is an alkene. As there are 3 carbon atoms in the final product, **L** is propene, C_3H_6.

Since only one chlorine atom is added into the molecule, the reaction of **M** with chlorine is a substitution reaction. Hence, **M** is an alkane. As there are 3 carbon atoms in the final product, **M** is propane, C_3H_8.

Both propene and propane can only be produced by the cracking of a larger alkane. Combining both the molecular formulae of propene and propane, the molecular formula of **K** will be C_6H_{14}.

11. **B**
Propyne will differ from ethyne by a $-CH_2-$ unit. Hence, propyne is C_3H_4.

Taking reference from the formula of ethyne and propyne, the general formula of alkynes is C_nH_{2n-2}.

C_nH_{2n-1} does not fulfil the bonding requirements of all the atoms. C_nH_{2n+2} is the general formula of alkanes while C_nH_{2n} is the general formula of alkenes.

12. **C**
The neutralisation equation between aqueous ammonia and propanoic acid is $NH_3 + C_2H_5COOH \longrightarrow C_2H_5COONH_4$.

13. **A**
The formula $C_5H_{12}O$ can also be written as $C_5H_{11}OH$. Since there is one oxygen atom in the molecule, the likely functional group in the molecule is the hydroxyl (–OH) group. Hence, the molecule is likely an alcohol.

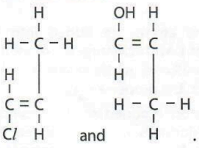
14. **D**
Alcohols undergo oxidation to form carboxylic acids by heating them with acidified potassium manganate(VII).

15. **D**
Compound **X** contains a carbon–carbon double bond and a carboxyl (–COOH) group. Hence, it can undergo addition reactions as well as acid-base reactions.
Option A and B are formed when **X** undergoes addition reactions with hydrogen and chlorine respectively.
Option C is formed when **X** reacts with sodium hydroxide to form the ionic salt.
Option D is not a possible product.

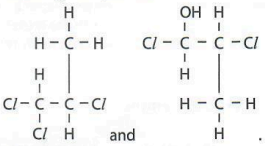
16. **A**
General formula of a carboxylic acid is $C_nH_{2n+1}COOH$. When $n = 12$, the formula of a saturated carboxylic acid is $C_{12}H_{25}COOH$. $C_{12}H_{27}COOH$ does not exist. $C_{12}H_{21}COOH$ and $C_{12}H_{23}COOH$ have less hydrogen atoms in their formulae compared to the saturated carboxylic acid formula. Hence, they contain carbon–carbon double bonds and may be unsaturated.

17. **C**
Option A is not true. Recycling involves transporting and sorting of both materials which adds on to the cost of recycling.
Option B is not true. The chemical method to recycle both materials is cracking. Converting them into small pellets is a physical method.
Option C is true. Marine animals may be endangered due to the improper disposal of both materials.
Option D is not true. Polyethene is formed from ethene while polypropene is formed from propene. Both ethene and propene contain a carbon–carbon double bond and hence are unsaturated.

18. **A**
From the structure of the polymer, the structure of the two alkenes are


and

Reacting the alkenes with chlorine would produce the following compounds


and

19. **A**
Carbon monoxide binds to the haemoglobin in blood, preventing it from transporting oxygen to the rest of the body. This can cause a loss of consciousness.

20. **C**
Cracking is a chemical method of recycling plastics while grinding and sorting are steps in the physical method of recycling plastics. Polymerisation is the process to form plastics.

21. **C**
Gases that cause global warming:
Carbon dioxide and methane
Gases that are neutral:
Nitrogen, oxygen and methane
Gases that can be removed by sodium hydroxide:
Carbon dioxide and nitrogen dioxide
Gases that can cause acid rain:
Nitrogen dioxide

22. **C**
M_r of $N_2 = 28$
M_r of $O_2 = 32$
M_r of $CO_2 = 44$
M_r of Ar = 40
Percentage of N_2 in air = 78 %
Percentage of O_2 in air = 21 %
Percentage of CO_2 in air = 0.44 %
Percentage of Ar in air = 0.56 %
Average relative molecular mass of air
$$= \frac{(78 \times 28) + (21 \times 32) + (0.44 \times 44) + (0.56 \times 40)}{100} = 29.0$$

23. **B**
$4Na + O_2 \longrightarrow 2Na_2O$
Volume of oxygen in the sample of dry air
$$= \frac{21}{100} \times 50 = 10.5 \text{ cm}^3$$
Number of moles of oxygen in the sample of dry air
$$= \frac{10.5}{1000} \div 24 = 0.0004375 \text{ mol}$$
Mole ratio $O_2 : Na_2O$
$= 1 : 2 = 0.0004375 : 0.000875$
Mass of Na_2O formed
$= 0.000875 \times (23 \times 2 + 16) = 0.0543$ g

24. **B**
When the sample of unpolluted air is ignited, nitrogen can react with oxygen to form nitrogen oxides like nitrogen monoxide and nitrogen dioxide. Argon is inert and hence would not react with other components in the air. Carbon monoxide is not present in unpolluted air.

25. **A**
The solution containing sulfuric acid and potassium manganate(VII) is used to remove reducing agents like sulfur dioxide gas. Aqueous sodium hydroxide is used to remove acidic gases like carbon dioxide, sulfur dioxide and hydrogen chloride. Aqueous bromine can react with alkenes like propene. Carbon monoxide, nitrogen, and alkanes are not removed by the three solutions.

Trial Examination 1

1. **C**
The spots of drugs **P** and **Q** matches the spots of the urine sample in both chromatograms. This shows that drugs **P** and **Q** are present in the urine sample.

2. **C**
A pure substance has a fixed melting point, while an impure substance or a mixture melt over a range of temperatures.

3. **A**
Option A is not true. 1 mol of chlorine-37 would have a greater mass than 1 mol of chlorine-35.

Option B is true. A chlorine molecule formed from two chlorine-37 isotopes would have a molecular mass of 37 + 37 = 74.

Option C is true. Both isotopes have the same number of electrons. Thus, they form the same anion Cl^- which has the electronic configuration 2, 8, 8.

Option D is true. Both isotopes have 17 protons and 17 electrons. Chlorine-37 has 20 neutrons. Thus, the total number of its sub-atomic particles is 17 + 17 + 20 = 54. Chlorine-35 has 18 neutrons. Thus, the total number of its sub-atomic particles is 17 + 17 + 18 = 52.

4. **C**
The valence electrons present in iron allow steel to conduct electricity.

5. **D**
Carbon disulfide is a covalent compound that exists as simple covalent molecules. Little energy is required to overcome the weak forces of attraction between its molecules. Thus, it has a low melting and boiling point.

6. **D**
Ammonia is a covalent compound with a low melting and boiling point. It exists as a gas at room temperature. Thus, its molecules are far apart from one another.

Ammonium chloride is an ionic compound with a high melting and boiling point. It exists as a solid at room temperature. Thus, its ions vibrate in their fixed positions.

7. **D**
$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$

Number of moles of H_2SO_4 reacted

$= \frac{25}{1000} \times 0.5$

$= 0.0125$ mol

From the equation, 1 mol of H_2SO_4 reacts with 2 mol of NH_3.

Number of moles of NH_3 reacted

$= 2 \times 0.0125$

$= 0.0250$ mol

Concentration of NH_3 reacted

$= 0.0250 \div \frac{20}{1000}$

$= 1.25$ mol/dm^3

8. **C**
Ammonia is an alkaline gas which turns damp red litmus paper blue.

Carbon dioxide, hydrogen bromide and sulfur dioxide are acidic gases which turn damp blue litmus paper red.

Carbon monoxide and nitrogen monoxide are neutral oxides which have no effect on damp litmus papers.

Hence, a total of four gases can change the colour of damp litmus papers.

9. **C**
Solution **J** produced effervescence when reacted with nitric acid. This shows that the carbonate ion was present as carbon dioxide was produced.

When sodium hydroxide was added into the mixture of solution **J** and nitric acid, which was then warmed, no precipitate was formed and no ammonia gas was produced. This shows that solution **J** did not contain calcium, aluminium and ammonium ions. Potassium and nitrate ions are thus not likely to have any reaction with dilute nitric acid and sodium hydroxide.

10. **A**
In option **A**, oxygen causes carbon to be oxidised and its oxidation state to increase from 0 in carbon to +2 in carbon monoxide. Hence, it is an oxidising agent.

In option **B**, lead(II) nitrate does not cause the oxidation states of sodium and chlorine in sodium chloride to change. Thus, it does not act as an oxidising agent.

In option **C**, hydrochloric acid does not cause the oxidation states of sodium, oxygen and hydrogen in sodium hydroxide to change. Thus, it does not act as an oxidising agent.

In option **D**, magnesium causes the oxidation state of zinc to decrease from +2 in zinc chloride to 0 in zinc. Thus, it acts as a reducing agent.

11. **D**
Element **W**, which is chlorine, is less reactive than element **Y**, which is fluorine. Element **Z**, which is potassium, is more reactive than element **X**, which is sodium. Hence, the elements that would react most vigorously with each other are **Y** and **Z**.

12. **B**
From the student's observations, it can be deduced that vanadium is more reactive than iron and copper, and nickel is more reactive than copper. Adding iron to nickel(II) ions would allow the student to find whether iron is more reactive than nickel and thus arrange the four metals in order of reactivity.

13. **B**
When excess aqueous potassium hydroxide and aqueous ammonia were added into sulfuric acid in experiments 1 and 2 respectively, the pH levels of the resultant solutions were higher than 7. Thus, the resultant solutions turned red litmus paper blue. The pH of the resultant solution in experiment 1 was higher than that in experiment 2 since potassium hydroxide is a strong alkali whereas ammonia is a weak alkali.

The temperature of the reaction mixture increased as neutralisation is an exothermic reaction.

When a drop of copper(II) sulfate was added into the resultant solution in experiment 1, a blue precipitate of copper(II) hydroxide was formed. When a drop of copper(II) sulfate was added into the resultant solution in experiment 2, a blue solution was formed. This is because copper(II) hydroxide dissolves in excess aqueous ammonia.

14. **D**
Statement 1 is not correct. A change in temperature affects the rate of reaction but not the volume of hydrogen produced.

Statement 2 is not correct. As nitric acid is the limiting reactant, changing its volume only changed its number of moles. This affected the volume of hydrogen gas produced but not the rate of reaction.

Statement 3 is correct. An increase in the concentration of nitric acid increases the rate of reaction and the number of moles of nitric acid. Thus, there was an increase in the volume of hydrogen gas produced as shown in graph **P**.

Statement 4 is not correct. The particle size of zinc only affects the rate of reaction but not the volume of hydrogen produced.

15. **C**
Option A is true. From the data in experiments 3 and 4, when the concentration of **D** is doubled, the time taken to produce **F** remains the same instead of being halved. This suggests that the concentration of **E** is decreased to 0.100 mol/dm^3.

Option B is true. From the data in experiments 1 and 2, doubling the concentration of **D** doubles the rate of reaction since the time taken for **F** to be produced is halved.

Option C is not true. From the data in experiments 2 and 3, doubling the concentration of **E** doubles the rate of reaction since the time taken for **F** to be produced is halved instead of remaining unchanged.

Option D is true. Since the concentrations of **D** and **E** affect the rate of reaction equally, doubling their concentrations would cause the time taken to decrease by four times and the rate of reaction to increase by four times.

16. **A**
Statement 1 is correct. The cracking of naphtha produces ethene which can be used to make plastics.

Statement 2 is correct. The hydrocarbons in petroleum are mainly alkanes with the general formula C_nH_{2n+2}. Thus, the chemical formula of an alkane with 8 carbon atoms, C_8H_{18}, is correct.

Statement 3 is not correct. Ethene obtained from the cracking of naphtha is used to form poly(ethene). Plastics made from poly(ethene) are resistant to corrosion and non-biodegradable.

Statement 4 is not correct. The boiling and melting points of molecules in a homologous series increases as molecular size increases. Thus, a molecule with 14 carbon atoms will likely have a higher boiling point than a molecule of the same homologous series with 7 carbon atoms.

17. **B**
Chlorine displaces sodium bromide or potassium bromide, forming aqueous bromine, which is a red-brown solution. Adding hexene to aqueous bromine causes hexene to undergo bromination and decolourise the red-brown solution.

18. **D**
Option A is true. Compound **Q** contains a carbon–carbon double bond. Thus, it can react with aqueous bromine.

Option B is true. Compound **Q** contains an alcohol functional group. Thus, it can be oxidised by acidified potassium manganate(VII).

Option C is true. The CH_3 group in compound **Q** can undergo substitution with chlorine in the presence of ultraviolet (UV) light.

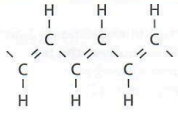
Option D is not true. The next member of the same homologous series as compound **Q** will have an additional $-CH_2-$ unit compared to the molecular formula of compound **Q**. Since the molecular formula of compound **Q** is C_4H_7OH, the next member should have a molecular formula of C_5H_9OH.

19. **C**
Option A is true.

$C_2H_2 + 2H_2 \longrightarrow C_2H_6$

Option B is true as hydrocarbons undergo complete combustion in the presence of excess oxygen to form carbon dioxide and water.

Option C is not true as ethyne undergoes addition polymerisation by breaking its carbon–carbon triple bond to form a polymer with carbon–carbon double bonds. Part of the structure is shown below.



Option D is true. The molecular formula of ethyne is C_2H_2. The next member of the homologous series will have an additional $-CH_2-$ unit compared to the molecular formula of ethyne. Hence, propyne has a molecular formula of C_3H_4.

20. **B**
Nitrogen molecules contain strong nitrogen–nitrogen triple bonds which require a lot of energy to break. Thus, they are stable and do not react easily.

Trial Examination 2

1. **D**
The magnesium chloride solution can be distilled to remove the water in the solution. A condenser, thermometer and a distillation flask are required. A filter funnel and separating funnel are not required.

2. **B**
Ethene reacts with aqueous chlorine via an addition reaction. Gas **X** cannot be hexane as hexane is a liquid at room temperature. Gas **X** could be hydrogen since it is less dense than air and can be collected by the upward delivery method. Solution **A** could be sodium hydroxide as it reacts with acidic hydrogen chloride.

3. **D**
Isotopes are atoms of the same element containing the same number of protons and electrons but different number of neutrons. Since deuterium has a greater atomic mass than hydrogen, it will contain more neutrons. Electrons are not found in the nucleus.

4. **C**
Since **B** and **C** are isotopes, they have the same atomic number of 12 (*w*). The mass number of **B** would be 12 + 13 = 25 (*u*). **B** and **C** are magnesium ion with 10 electrons (*y*) and a charge of +2 (*z*). Since **A** has a charge of +1 and a mass number of 23, it would be sodium with an atomic number of 11 (*v*). The number of electrons present in Na^+ would be 10 (*x*).

5. **D**
X is a metal whereas **Y** is a non-metal. **X** loses 3 electrons to form the cation X^{3+} while **Y** gains 2 electrons to for the anion Y^{2-}. An ionic compound of the formula X_2Y_3 will be formed where a total of 6 electrons are involved. If **X** is aluminium while **Y** is oxygen, the relative molecular mass of Al_2O_3 is 102.

6. **D**
In alloys, the different sized atoms disrupt the orderly arrangement of the metal atoms. This prevents the layers from sliding past each other easily, strengthening the metal.

7. **A**
$Ba(OH)_2 + 2HCl \longrightarrow BaCl_2 + 2H_2O$

Number of moles of $Ba(OH)_2$

$= \frac{30}{1000} \times 1.0 = 0.0300$ mol

Number of moles of HCl

$= \frac{40}{1000} \times 1.0 = 0.0400$ mol

Mole ratio $Ba(OH)_2$: HCl

= 1 : 2 = 0.0300 : 0.0600

0.03 mol of $Ba(OH)_2$ reacts with 0.06 mol of HCl. Since only 0.0400 mol of HCl is present, it is the limiting reactant.

Number of moles of $Ba(OH)_2$ reacted

= 0.0400 ÷ 2 = 0.0200 mol

Number of moles of $Ba(OH)_2$ unreacted
$= 0.0300 - 0.0200 = 0.0100$ mol
Total volume of solution
$= 30 + 40 = 70\ cm^3 = 0.0700\ dm^3$
Concentration of unreacted $Ba(OH)_2$
$= \frac{0.0100}{0.0700} = 0.143\ mol/dm^3$

8. **D**
Number of moles of KOH
$= \frac{28.4}{1000} \times 1.5 = 0.0426$
Mole ratio of KOH : H_2SO_4
$= 2 : 1 = 0.0426 : 0.0213$
Number of moles of H_2SO_4
$= \frac{100}{1000} \times 1.2 = 0.120$
Number of moles of H_2SO_4 reacted with Fe_2O_3
$= 0.120 - 0.0213 = 0.0987$
Mole ratio of $H_2SO_4 : Fe_2O_3$
$= 3 : 1 = 0.0987 : 0.0329$
Number of moles of $Fe_2O_3.xH_2O$
= Number of moles of Fe_2O_3 reacted
$= 0.0329$ mol
M_r of $Fe_2O_3.xH_2O$
$= 10 \div 0.0329 = 304$
M_r of Fe_2O_3
$= 2 \times 56 + 3 \times 16 = 160$
M_r of xH_2O
$= 304 - 160 = 144$
$x = 144 \div 18 = 8$

9. **C**
Statement 1 is not correct. Magnesium can conduct electricity due to the presence of mobile electrons while magnesium propanoate solution conducts electricity due to the presence of mobile ions.
Statement 2 is correct. Zinc is less reactive than magnesium and hence would not react as vigorously with ethanoic acid. The effervescence of hydrogen gas would not be as vigorous as well.
Statement 3 is correct. Magnesium is oxidised in the reaction. The oxidation state of magnesium increases from 0 in Mg to +2 in $(C_3H_7COO)_2Mg$.
Statement 4 is not correct.
Number of moles of magnesium
$= 1.2 \div 24 = 0.0500$ mol
1 mol of magnesium reacts to form 1 mol of hydrogen gas.
Number of moles of hydrogen
$= 0.0500$ mol
Volume of hydrogen gas produced
$= 0.0500 \times 24\ dm^3 = 1.2\ dm^3$

10. **B**
Solid **G** is a carbonate since it produces carbon dioxide when an acid is added. When heated, the carbonate decomposes into an oxide. The identity of oxide **H** is zinc oxide since it is the only oxide that turns yellow when heated and white when cooled. Hence, solid **G** is zinc carbonate while oxide **H** is zinc oxide, which is an amphoteric oxide.

11. **C**
In step 1, oxygen is acting as the oxidising agent since it caused the oxidation of C. The oxidation state of carbon increases from 0 in C to +4 in CO_2.
In step 2, carbon is the reducing agent since it caused the reduction of CO_2. The oxidation state of carbon decreases from +4 in CO_2 to +2 in CO.
In step 3, carbon monoxide is acting as the reducing agent since it causes the reduction of Fe_2O_3. The oxidation state of iron decreases from +3 in Fe_2O_3 to 0 in Fe.
Steps 4 and 5 are not redox reactions since there are no changes in the oxidation states of the reactants and products.

12. **C**
The reactivity of elements does not decrease across the period since it can only be compared between metals and non-metals. For example, Group 1 elements are the most reactive metals while Group 17 elements are the most reactive non-metals.

13. **D**
Option A is true. When sodium is added into water, sodium hydroxide and hydrogen gas are formed. Hydrogen gas extinguishes a burning splint with a "pop" sound.
Option B is true. Since sodium burst into flames when added to water, the reaction produced a lot of thermal energy. This indicates that it is an exothermic reaction.
Option C is true. Potassium is below sodium in the periodic table. Hence, potassium is a more reactive metal than sodium. It would react more vigorously with water.
Option D is not true. Since the reaction is exothermic, the temperature of the reaction mixture should increase and not decrease to 20 °C during the reaction.

14. **A**
A more reactive metal forms a more stable carbonate. Hence, statement 4 is not true. A more stable carbonate takes a longer time to decompose. As such, **W** is the most reactive metal followed by **Y**, **X** and **Z**.
Statement 1 is true. **W** could be placed high in the reactivity series and thus could be able to react with cold water.
Statement 2 is not true. As **X** is less reactive than **Y**, **X** will not be able to displace **Y** from its chloride solution.
Statement 3 is true. Since **Y** is more reactive than **Z**, **Y** will displace **Z** from its nitrate solution.

15. **C**
In sublimation and evaporation, intermolecular forces of attraction are overcome, not covalent bonds. Therefore, option C is not true.

16. **A**
Adding sulfuric acid with a lower concentration will cause the overall concentration of the sulfuric acid to decrease. This causes the rate of reaction to decrease.
Crushing the zinc granules into a powder increases the surface area of zinc. This increases the rate of reaction.
Increasing the pressure of the reaction mixture will not affect the rate of reaction as the reactants are not in the gaseous state and thus cannot be compressed.
Increasing the temperature of the reaction would increase the kinetic energy of the reactant particles. This causes the rate of reaction to increase.
Magnesium is more reactive than zinc and hence will react more vigorously with the acid.

17. **B**
Burning bioethanol produces carbon dioxide, which is a greenhouse gas. Hence, burning bioethanol will still produce gases which might harm the environment.

Bioethanol is a renewable resource since it is obtained from plant or animal matter. Petrol and diesel are obtained from crude oil, which is a non-renewable resource.

Bioethanol is obtained from plant and animal matter, not from petroleum.

Producing bioethanol might cost more than producing petrol and diesel. Time and money are required to process and transport the plant and animal matter needed for bioethanol.

18. **D**
Statement 1 is not correct. Equation 2 involves the addition of bromine to an alkene with a general formula of C_nH_{2n}. Based on the chemical formula of the alkene, $2n = 4$, hence $n = 2$.

Statement 2 is not correct. The product of equation 1 has the formula $C_2H_4Br_2$. In order to form the product from ethane, 1 mol of ethane has to react with 2 mol of chlorine gas in the presence of ultraviolet (UV) light.

Statement 3 is correct. Equation 3 is the oxidation of methanol to methanoic acid. Hence, ethanol can also be oxidised to ethanoic acid in the same manner.

Statement 4 is correct. Product **Y** in equation 2 is ethanol. When exposed to air for some time, the oxygen in the air will oxidise ethanol to ethanoic acid.

19. **D**
Option A is formed when compound **P** is oxidised.

Option B is formed when compound **P** undergoes an addition reaction with hydrogen.

Option C is formed when compound **P** undergoes addition polymerisation.

Option D cannot be formed because there is no reaction which involves the shifting of the hydroxyl (–OH) group in the molecule.

20. **C**
Statement 1 is not true. As the intake of air increases, more oxygen would be present. Hence, there is a greater extent of complete combustion. This decreases the likelihood of carbon monoxide being produced. Hence, the volume of carbon monoxide produced would not be similar to that of the nitrogen oxides.

Statement 2 is true. When the intake of air is high, the volume of C_xH_y released is low. This indicates that more petrol is burnt in the car engine.

Statement 3 is true. Carbon monoxide is the reducing agent used to remove nitrogen oxides in the catalytic converter. Hence, the volume of nitrogen oxides removed by catalytic converters decreases.

Statement 4 is true. When the intake of air is low, there is a decrease in the formation of nitrogen oxides. This shows that the temperature of the engine is low since nitrogen oxides form in the combustion engine of the car.

N Trial Examination 3

1. **C**
The spots of drugs **P** and **Q** matches the spots of the urine sample in both chromatograms. This shows that drugs **P** and **Q** are present in the urine sample.

2. **C**
A pure substance has a fixed melting point while an impure substance or a mixture melt over a range of temperatures.

3. **A**
Option A is not true. 1 mol of chlorine-37 would have a greater mass than 1 mol of chlorine-35.

Option B is true. A chlorine molecule formed from two chlorine-37 isotopes would have a molecular mass of $37 + 37 = 74$.

Option C is true. Since both isotopes have the same number of electrons. Thus, they will form the same anion Cl^- which has the electronic configuration 2, 8, 8.

Option D is true. Both isotopes have 17 protons and 17 electrons. Chlorine-37 has 20 neutrons. Thus, the total number of its sub-atomic particles is $17 + 17 + 20 = 54$.

Chlorine-35 has 18 neutrons. Thus, the total number of its sub-atomic particles is $17 + 17 + 18 = 52$.

4. **C**
The valence electrons present in iron allow steel to conduct electricity.

5. **D**
Carbon disulfide is a covalent compound that exists as simple covalent molecules. Little energy is required to overcome the weak forces of attraction between its molecules. Thus, it has a low melting and boiling point.

6. **D**
Ammonia is a covalent compound with low melting and boiling points. It exists as a gas at room temperature. Thus, its molecules are far apart from one another. Ammonium chloride is an ionic compound with high a melting and boiling point. It exists as a solid at room temperature. Thus, its ions vibrate in their fixed positions.

7. **B**
Chemical equation:

$BaCl_2(aq) + CuSO_4(aq) \longrightarrow BaSO_4(s) + CuCl_2(aq)$

Ionic equation:

$Ba^{2+}(aq) + \cancel{2Cl^-(aq)} + \cancel{Cu^{2+}(aq)} + SO_4^{2-}(aq)$

$\longrightarrow BaSO_4(s) + \cancel{Cu^{2+}(aq)} + \cancel{2Cl^-(aq)}$

$Ba^{2+}(aq) + SO_4^{2-}(aq)$ $BaSO_4(s)$

8. **B**
Only amphoteric oxides can react with both acids and alkalis. Acidic oxides can react with alkalis whereas basic oxides can react with acids. Neutral oxides cannot react with both acids and alkalis.

Amphoteric oxides: Aluminium oxide and zinc oxide

Acidic oxide: Carbon dioxide

Basic oxide: Magnesium oxide

Neutral oxides: Carbon monoxide and nitrogen monoxide

9. **A**
Since the relative atomic mass of **M** is 40, it is likely calcium. Solid **Q** is calcium carbonate while gas **R** is carbon dioxide. Heating **Q** forms calcium oxide and carbon dioxide. Reacting **Q** with nitric acid also produces carbon dioxide gas.

M_r of calcium carbonate

$= 40 + 12 + (3 \times 16) = 100$

M_r of carbon dioxide

$= 12 + (2 \times 16) = 44$

Hence,

Mass of 1.0 mol of calcium carbonate

$= 1 \times 100 = 100$ g

Mass of 0.5 mol of calcium carbonate

$= 0.5 \times 100 = 50$ g

Mass of 1.0 mol of carbon dioxide

$= 1.0 \times 44 = 44$ g

Mass of 0.5 mol of carbon dioxide

$= 0.5 \times 44 = 22$ g

10. **B**

$2KOH(aq) + H_2SO_4(aq) \longrightarrow K_2SO_4(aq) + 2H_2O(l)$

$2KOH(aq) + H_2SO_4(aq) \longrightarrow CaSO_4(s) + 2H_2O(l)$

When excess potassium hydroxide or calcium hydroxide is added into sulfuric acid, the resultant solution has a pH greater than 7.

When aqueous calcium hydroxide is added to sulfuric acid, calcium sulfate, which is a white solid, and water are formed. Since ions are removed from the solution, the electrical conductivity of the solution decreases.

When an excess of potassium hydroxide is added into sulfuric acid, no solid is formed. Hence, the resultant solution still contains a high concentration of ions that can act as mobile charge carriers. Therefore, the electrical conductivity of the solution did not decrease. The ionic equation of a neutralisation reaction is $H^+ + OH^- \longrightarrow H_2O$.

11. **D**

Gas **K** is hydrogen. When reacted with oxygen, which is Gas **L**, water is formed. Water is a liquid compound that boils at 100 °C.

12. **D**

Element **W**: Chlorine

Element **X**: Sodium

Element **Y**: Fluorine

Element **Z**: Potassium

Hence, the combination of elements which will react most vigorously will be **Y** and **Z**.

13. **C**

Vanadium is the most reactive metal of the four as it displaces all the metals from their chloride solutions. Iron is the next most reactive metal since it can displace nickel and copper from their chloride solutions but not vanadium. Nickel is less reactive than iron and vanadium but more reactive than copper since it can only displace copper from its chloride solution. Copper is the least reactive metal since it is unable to displace any metals from their chloride solutions.

14. **A**

Coating iron with plastic, paint or copper prevents iron from coming into contact with oxygen and water vapour in air. This prevents iron from rusting. Sodium chloride will speed up the rusting process of iron.

15. **A**

Statement 1 is correct. Ethene can be formed from the cracking of naphtha, which is subsequently used to make plastics.

Statement 2 is correct. The hydrocarbons in crude oil are mainly alkanes with a general formula of C_nH_{2n+2}. The formula of a hydrocarbon with $n = 8$ is C_8H_{18}.

Statement 3 is not correct. Plastics made from polyethene are not easily broken down by bacteria and other organisms and thus are non-biodegradable.

Statement 4 is not correct. The melting and boiling points of molecules increases down the homologous series. Hence, a molecule with 14 carbon atoms will have a higher boiling point than a molecule with 7 carbon atoms.

16. **B**

The red-brown solution is likely aqueous bromine. Therefore, **J** is likely chlorine since chlorine can displace bromine from its halide solution. Hence, **K** can be either sodium bromide or potassium bromide. Adding hexene to aqueous bromine causes the addition of bromine onto hexene, thus decolourising the red-brown solution.

17. **B**

The name of the molecule after methanoic acid will be ethanoic acid. Propanoic acid has a formula of C_2H_5COOH whereas butanoic acid has a formula of C_3H_7COOH since each subsequent member of the homologous series has an additional $-CH_2-$ unit.

18. **A**

Options B and D are true. Compound **X** contains a carbon–carbon double bond. Thus, it is able to react with aqueous iodine and also undergo addition polymerisation.

Option C is true. The $-CH_3$ groups in compound **X** can undergo substitution with chlorine in the presence of ultraviolet (UV) light.

Option A is not true. Compound **X** cannot dissolve in water as it is an organic molecule which can only dissolve in organic solvents.

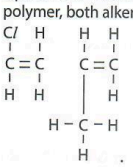
19. **C**

Option A cannot be formed as the hydrogen atom in the middle of the molecule contains two bonds.

Option B cannot be formed as the two alkenes are not joined at the correct carbon atoms where the carbon–carbon double bonds are situated.

Option D cannot be formed as the $-CH_3$ and the $-Cl$ groups are on the same alkene.

Option C is the correct structure formed. To form the polymer, both alkenes must be in the configuration of



20. **B**

Nitrogen molecules contain strong nitrogen–nitrogen triple bonds which require a lot of energy to break. Thus, nitrogen molecules are stable and do not react easily.

Trial Examination 4

1. **D**

The magnesium chloride solution can be distilled to remove the water in the solution. A condenser, thermometer and a distillation flask are required. A filter funnel and separating funnel are not required.

2. **D**

Based on the chromatogram, **A** contains spots that matches dyes 1 and 2. Hence, it is a mixture containing two dyes. Similarly, **B** contains spots that matches dyes 2 and 3. Hence, it is also a mixture containing two dyes.

3. **B**
Ethene reacts with aqueous chlorine via an addition reaction. Gas **X** cannot be hexane as hexane is a liquid at room temperature. Gas **X** could be hydrogen since it is less dense than air and can be collected by the upward delivery method. Solution **A** could be sodium hydroxide as it reacts with acidic hydrogen chloride.

4. **C**
In sublimation and evaporation, intermolecular forces of attraction are overcome, not covalent bonds. Therefore, option C is not true.

5. **D**
Isotopes are atoms of the same element containing the same number of protons and electrons but different number of neutrons. Since deuterium has a greater atomic mass than hydrogen, it will contain more neutrons. Electrons are not found in the nucleus.

6. **C**
Since **B** and **C** are isotopes, they have the same atomic number of 12 (*w*). The mass number of **B** would be 12 + 13 = 25 (*u*). **B** and **C** are magnesium ion with 10 electrons (*y*) and a charge of +2 (*z*). Since **A** has a charge of +1 and a mass number of 23, it would be sodium with an atomic number of 11 (*v*). The number of electrons present in Na^+ would be 10 (*x*).

7. **D**
X is a metal whereas **Y** is a non-metal. **X** loses 3 electrons to form the cation X^{3+} while **Y** gains 2 electrons to for the anion Y^{2-}. An ionic compound of the formula X_2Y_3 will be formed where a total of 6 electrons are involved. If **X** is aluminium while **Y** is oxygen, the relative molecular mass of Al_2O_3 is 102.

8. **D**
In alloys, the different sized atoms disrupt the orderly arrangement of the metal atoms. This prevents the layers from sliding past each other easily, strengthening the metal.

9. **C**
M_r of $WO_2 = \frac{22.0}{0.500} = 44$

A_r of **W** = 44 – (2 × 16) = 12

Element **W** is carbon, which is in Group 14 and has 4 valence electrons.

M_r of $XF_3 = \frac{12.6}{0.150} = 84$

A_r of **X** = 84 – 3 × 19 = 27

Element **X** is aluminium, which is in Group 13 and has 3 valence electrons.

M_r of $YCl = \frac{29.8}{0.400} = 74.5$

A_r of **Y** = 74.5 – 35.5 = 39

Element **Y** is potassium, which is in Group 1 and has 1 valence electron.

M_r of $Z(NO_3)_2 = \frac{14.8}{0.100} = 148$

A_r of **Z** = 148 – (2 × 14 + 6 × 16) = 24

Element **Z** is magnesium, which is in Group 2 and has 2 valence electrons.

Hence, element **W** has the most valence electrons followed by elements **X**, **Z** and **Y**.

10. **D**
Aluminium oxide does not react with sodium hydroxide to produce any gas. Calcium oxide is a basic oxide. Hence, it does not react with ammonia, which is an alkali. Ammonium chloride and ammonium sulfate will react with alkalis like potassium hydroxide or sodium hydroxide to produce ammonia gas.

11. **D**
Statement 1 is not correct. Copper is an unreactive metal and hence would not react with ethanoic acid.

Statement 2 is not correct. When dissolved in organic solvents, ethanoic acid does not dissociate to form hydrogen ions. Hence, there will be no reaction with magnesium.

Statement 3 is correct. When magnesium carbonate reacts with ethanoic acid, carbon dioxide gas is produced. The same observation will be seen as effervescence of a colourless gas occurs.

Statement 4 is not correct. Magnesium oxide is a basic oxide that reacts with ethanoic acid to form magnesium ethanoate and water. No gas is formed in this reaction.

12. **A**
Option A is not true. The products of burning methane are carbon dioxide gas and water. Carbon dioxide gas cannot be identified using damp red litmus paper as it is an acidic oxide. It can be identified using damp blue litmus paper instead.

Option B is true. Zinc reacts with nitric acid to form hydrogen gas. Hydrogen gas extinguishes a burning splint with a "pop" sound.

Option C is true. Both reactions produce carbon dioxide gas.

Option D is true. Ammonium chloride can decompose to form ammonia gas and hydrogen chloride gas. Ammonia gas will turn damp red litmus paper blue while hydrogen chloride gas will turn damp blue litmus paper red.

13. **C**
The reactivity of elements does not decrease across the period since it can only be compared between metals and non-metals. For example, Group 1 elements are the most reactive metals while Group 17 elements are the most reactive non-metals.

14. **A**
The reactivity of Group 17 elements decreases down the group. Therefore, the reactivity of the elements is as follows:

Cl > Br > I

Therefore, chlorine is able to displace bromine and iodine from their halide solutions. Bromine is able to displace iodine from its halide solution.

15. **B**
Statement 1 is true. SV_2 is a gas at room temperature which makes it likely to be a covalent compound. Hence, the sulfur atom would share 2 electrons with two atoms of an element from Group 17 to form SV_2.

Statement 2 is not true. If element **V** is sodium, SV_2 would be an ionic compound. Ionic compounds have high melting and boiling points. Thus, they exist as solids at room temperature.

Statement 3 is not true. Since SV_2 is likely to be a covalent compound, it would contain molecules instead of ions.

Statement 4 is true. The formula SV_2 could represent that of sulfur dioxide, SO_2.

16. **B**

O displaces **P**. Hence, **O** is more reactive than **P**. **Q** displaces **O**. Hence, **Q** is more reactive than **O** and **P**. **R** displaces **Q**. Hence, **R** is more reactive than **Q**, **O** and **P**.

As such, option A is correct since **Q** is able to displace **P**.

Option B is incorrect as **Q** cannot displace **R**.

Option C is correct as **R** can displace **O**.

Option D is correct as **R** can displace the **P**.

17. **B**

Burning bioethanol produces carbon dioxide, which is a greenhouse gas. Hence, burning bioethanol will still produce gases which might harm the environment.

Bioethanol is a renewable resource since it is obtained from plant or animal matter. Petrol and diesel are obtained from crude oil, which is a non-renewable resource.

Bioethanol is obtained from plant and animal matter, not from petroleum.

Producing bioethanol might cost more than producing petrol and diesel. Time and money are required to process and transport the plant and animal matter needed for bioethanol.

18. **D**

Since organic compound **M** has more bromine atoms than organic compound **N**, the reaction to form organic compound **M** would be an addition reaction involving the addition of bromine to ethene. The equation is $C_2H_4 + Br_2 \longrightarrow C_2H_4Br_2$.

The reaction to form organic compound **N** would be a substitution reaction involving ethane and bromine. The equation is $C_2H_6 + Br_2 \longrightarrow C_2H_5Br + HBr$.

As such, $x = 4$, $y = 6$. Hence, statement 4 is correct.

Statement 1 is not correct. No by-products are formed in an addition reaction.

Statement 2 is correct. Ethene and ethane can be formed from the cracking of a larger alkane molecule.

Statement 3 is not correct. Organic compound **N** has one more hydrogen atom than organic compound **M**.

19. **C**

Statement 1 is not true.

Carbon–hydrogen bonds are not broken during addition polymerisation. The carbon–carbon double bond is broken instead.

20. **C**

Statement 1 is not true. As the intake of air increases, more oxygen would be present. Hence, there is a greater extent of complete combustion. This decreases the likelihood of carbon monoxide being produced. Hence, the volume of carbon monoxide produced would not be similar to that of the nitrogen oxides.

Statement 2 is true. When the intake of air is high, the volume of C_xH_y released is low. This indicates that more petrol is burnt in the car engine.

Statement 3 is true. Carbon monoxide is the reducing agent used to remove nitrogen oxides in the catalytic converter. Hence, the volume of nitrogen oxides removed by catalytic converters decreases.

Statement 4 is true. When the intake of air is low, there is a decrease in the formation of nitrogen oxides. This shows that the temperature of the engine is low since nitrogen oxides form in the combustion engine of the car.