

CHEMISTRY

Units 3 & 4 – Written examination



2024 Trial Examination

SOLUTIONS

SECTION A: Multiple-choice questions (1 mark each)

Question 1

Correct Answer: C

Explanation:

Bioethanol is considered a more sustainable option than petrol because it can be produced from renewable resources like crops, which can be regrown in relatively short periods (months), thus providing a renewable source of energy.

Question 2

Correct Answer: C

Explanation:

Reversing the direction of a chemical reaction changes the sign of ΔH but keeps its magnitude the same. This is based on the principle that the amount of energy released or absorbed in a reaction is intrinsic to the reaction itself, regardless of the direction in which it proceeds. The sign change reflects whether energy is being absorbed (endothermic, positive ΔH) or released (exothermic, negative ΔH).

Question 3

Correct Answer: C

Explanation:

The calibration factor (CF) in calorimetry is crucial for adjusting measurements to account for heat losses to the surroundings and the calorimeter wall. By establishing how much energy corresponds to a unit change in temperature, the CF allows for more accurate calculation of the actual energy changes in chemical reactions or material testing, compensating for system inefficiencies.

Question 4

Correct Answer: A

Explanation:

The percentage energy efficiency can be calculated using the formula

$$\% \text{ energy efficiency} = \frac{\text{actual or experimental value (e.g. useful energy output)}}{\text{theoretical value (e.g. chemical energy input)}} \times 100\%$$

Substituting the values in the formula $\therefore \% \text{ energy efficiency} = \left(\frac{90}{120} \right) \times 100\%$

This result shows that 75% of the theoretical energy was effectively utilised as useful energy.

Question 5

Correct Answer: B

Explanation.

According to the priority list of functional groups in VCAA data book, page 15, the hydroxy group is higher priority which determines the suffix of the compound. The amino group becomes branch. Numbering starts from the side closer to -OH functional group.

Question 6

Correct answer: B

Explanation:

During photosynthesis, plants convert light energy from the sun into chemical energy, which is stored in the bonds of glucose.

Question 7

Correct Answer: A

Explanation:

In the given reaction, oxygen molecules gain electrons when they react with glucose, thus they are reduced. This can be observed from the gain of hydrogen atoms in water, a reduction process.

Question 8

Correct Answer: B

Explanation:

Photosynthesis is non-spontaneous because it requires an input of energy to proceed (from sunlight), converting this energy into chemical energy stored in glucose. Conversely, cellular respiration is spontaneous as it releases energy stored in glucose.

Question 9

Correct answer: C

Explanation:

The salt bridge allows ions to flow between the two half-cells, which is necessary to balance the charges as electrons flow through the external circuit. Without the salt bridge, the flow of electrons would stop as the solutions in each half-cell would become charged.

Question 10

Correct answer: C

Explanation:

The anode is the electrode where oxidation occurs. Zinc is more reactive than silver, so it loses electrons (is oxidised) more readily. Hence, the Zn(s) electrode is the anode.

Question 11

Correct answer: D

Explanation:

Since the Zn(s) electrode is the anode where oxidation occurs, it loses mass as zinc atoms lose electrons and enter the solution as Zn^{2+} ions.

Question 12

Correct answer: C

Explanation:

As the name 'solid oxide fuel cell' suggests, the electrolyte is typically made of a ceramic, solid oxide material which conducts ions at high temperatures.

Question 13

Correct answer: C

Explanation:

The diagram shows CO₂ being released at the anode side as a result of the oxidation of methane.

Question 14

Correct answer: C

Explanation:

The electrolyte in SOFCs must have high ionic conductivity at high temperatures to efficiently conduct hydrogen ions from the anode to the cathode while maintaining its structural integrity.

Question 15

Correct Answer: B

Explanation.

Green hydrogen is specifically termed for hydrogen produced by splitting water into hydrogen and oxygen using electrolysis powered by renewable energy sources such as solar, wind, or hydroelectric power. This method does not emit carbon dioxide or other greenhouse gases during the production process, making it a sustainable and environmentally friendly option.

Question 16

Correct Answer: C

Explanation:

The longer carbon chains in diesel lead to stronger intermolecular forces, particularly London dispersion forces, between the molecules. This increased attraction between molecules contributes to higher viscosity.

Question 17

Correct Answer: B

Explanation:

An increase in temperature provides more thermal energy to the molecules of the liquid. This added energy allows the molecules to overcome intermolecular attractions more easily, enabling them to move past each other more freely. As a result, the viscosity of the liquid decreases with increased temperature.

Question 18

Correct Answer: C

Explanation:

Cooking oil is primarily composed of non-polar molecules that interact through dispersion forces, which are the weakest type of intermolecular forces.

Question 19

Correct Answer: D

Explanation:

Octane has the highest boiling point as the number of carbon atoms in the alkane chain increases, the boiling point also tends to increase due to the larger surface area allowing for stronger dispersion forces. These intermolecular forces become stronger with increased molecular weight, requiring more heat energy to overcome them and turn the substance into a gas.

Question 20

Correct Answer: B

Explanation:

The hydrogenation of ethene involves the addition of hydrogen (H_2) across the double bond of ethene, resulting in the formation of ethane ($\text{CH}_3\text{-CH}_3$). This reaction requires a metal catalyst such as nickel and the application of heat.

Question 21

Correct Answer: B

Explanation:

The hydration of ethene to produce ethanol requires a strong acid catalyst. In this case, concentrated phosphoric acid (H_3PO_4) is used, along with heat and high pressure, to facilitate the addition of water across the double bond.

Question 22

Correct Answer: B

Explanation:

Catalysis improves the selectivity of chemical reactions, meaning that the reactions can occur with greater specificity. This leads to minimisation or elimination of unwanted by-products, reducing waste and saving costs by improving the yield of the desired product. Enhanced selectivity is fundamental in green chemistry to ensure resource efficiency and reduce the generation of waste.

Question 23

Correct Answer: D

Explanation:

Catalysts can lower the activation energy required for a reaction, which means that reactions can occur at lower temperatures and pressures than would otherwise be needed. This reduction in energy requirements not only conserves energy but can also lead to lower carbon emissions, aligning with the principles of green chemistry.

Question 24

Correct Answer: A

Explanation:

Alkanes are saturated hydrocarbons and do not have carbon-carbon double bonds that can react with bromine. Bromine water reacts with alkenes through an addition reaction at the double bond, leading to the decolorization of bromine. This test is specific to unsaturation, which alkanes lack, hence they do not show a color change when treated with bromine water.

Question 25

Correct Answer: D

Explanation:

Several factors could contribute to the lack of bubbling even if a carboxyl group is present. A low concentration of the carboxylic acid may not produce enough CO₂ to be visible as bubbling. If the metal carbonate is not sufficiently reactive or if something in the solution has neutralized the carboxylic acid (such as a strong base), then the expected reaction may not occur. Each of these scenarios could individually or collectively explain the absence of bubbling.

Question 26

Correct Answer: D

Explanation:

The iodine value (IV) is a measure of the unsaturation in a fat or oil, indicated by the number of grams of iodine that can react with 100 grams of the substance. A higher IV corresponds to a greater number of carbon-carbon double bonds present in the fat or oil, which means a higher degree of unsaturation.

Question 27

Correct Answer: C

Explanation:

The proton NMR spectrum shows a singlet peak at around 2 ppm, indicative of a methyl group adjacent to a carbonyl group, and a triplet around 1-1.5 ppm typical for -CH₂- protons. Based on this data, the molecule corresponds to butan-2-one.

Question 28

Correct Answer: C

Explanation:

Achiral compounds are those whose structures are superimposable on their mirror images. This means that the molecule and its mirror image are identical, indicating no chiral centers or asymmetry within the molecule

Question 29

Correct Answer: C

Explanation:

The lock-and-key model proposes that the active site of an enzyme is specifically shaped to fit a particular substrate, much like a key fits into a lock, without the need for alteration of the substrate or active site upon binding.

Question 30

Correct Answer: B

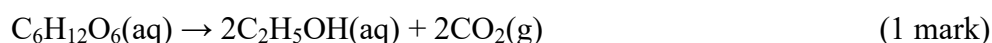
Explanation:

Enzymes require specific pH levels to maintain their 3D structure and function effectively. Changes in pH can affect the charges and bonding within the enzyme, particularly at sites critical for maintaining its structure. Disruption of ionic and hydrogen bonds by altered H^+ or OH^- concentrations can lead to denaturation, thereby affecting the enzyme's catalytic activity.

SECTION B: Short-answer questions**Question 1****a.**

Ethanol is commonly produced from plants through a process called fermentation, in which yeast uses enzymes to break down plant glucose to produce ethanol and CO₂. (1 mark)

The simplified chemical equation for this biochemical reaction is:

**b.**

2 marks for any of the two reasons.

- **Reduced Greenhouse Gas Emissions:** Biofuels, especially when derived from renewable organic materials, can significantly reduce greenhouse gas emissions compared to fossil fuels.
- **Lower Emissions of Pollutants:** When burned, pure biofuels generally produce fewer emissions of particulates, sulfur dioxide, and air toxics compared to fossil fuels.
- **Sustainability:** Biofuels are produced from renewable resources such as plants, which can be replanted and harvested regularly and ensure sustainability of biofuels.
- **Public Health Benefits:** Using biodiesel as a vehicle fuel can improve public health by reducing the emission of harmful pollutants. This contributes to a cleaner environment and healthier communities

c.

Land use and must be considered when evaluating the sustainability of biofuels.

(2 marks for any two of the following. Reward marks for other acceptable answers)

For example:

- if the production of biofuels requires deforestation or conversion of peatlands, it can lead to high upfront carbon emissions which may negate the benefits over several years or decades.
- Land use change for biofuel production can lead to increased greenhouse gas emissions, soil erosion, nutrient depletion, and water contamination, impacting ecosystems and biodiversity

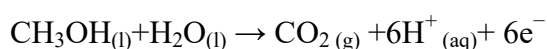
- Expansion of biofuel cultivation can drive indirect land use changes, such as deforestation in other regions, exacerbating environmental degradation and biodiversity loss.
- Biofuel crops may compete with food crops for arable land, raising concerns about food security, land degradation, and increased food prices

Question 2

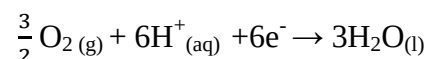
a.

1 mark for each correct equation with

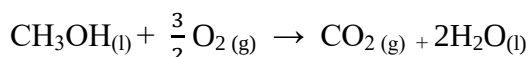
At anode



At cathode



Overall



b.

Increasing the thickness of the Polymer Electrolyte Membrane may decrease fuel cell efficiency (1 mark) due to the added resistance to proton flow (1)

c.

A layer of catalyst is added on both sides of the membrane—the anode layer on one side and the cathode layer on the other.

This catalyst is necessary because it increases the rate of reaction (1 mark) by lowering the activation energy of the oxidation and reduction reactions happening at cathode and anode via providing an alternative reaction pathway (1 mark)

In the absence of catalyst, the reactions would proceed too slowly to be practical for energy production. (1 mark)

d.

A catalyst is chemically involved in a reaction but remains chemically unchanged once the reaction is complete. It is not consumed by the reaction and can be recovered in its original form (1 mark).

However, catalysts can undergo physical alterations during a reaction, such as poisoning where a foreign substance adsorb strongly to the catalyst's active sites, modifying their

number or structure. This alteration can reduce the catalyst's effectiveness or activity. (1 mark)

Question 3

a.

When the temperature is increased in the $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ and CoCl_4^{2-} equilibrium system, the equilibrium position shifts to the right towards the production of more CoCl_4^{2-} (blue) (1 mark)

This shift occurs because the reaction is endothermic (1 mark), and according to Le Chatelier's principle, increasing the temperature favors the endothermic direction of the reaction, which in this case forms more of the blue complex ion. (1 mark)

b.

Adding concentrated hydrochloric acid to the solution increases the chloride ion concentration (1 mark), which according to Le Chatelier's principle, shifts the position of the equilibrium to the right (1 mark). This results in the formation of more $[\text{CoCl}_4]^{2-}$ (blue), changing the color of the solution from pink to blue. (1 mark)

c.

Initially, there is 1.0 M of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$

If 60% of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ becomes $[\text{CoCl}_4]^{2-}$, then the final remaining concentration of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ is $100\% - 60\% = 40\%$ (1 mark)

40% of 1 M = $\frac{40}{100} \times 1.0 \text{ M} = 0.40 \text{ M}$ (1 mark)

Question 4

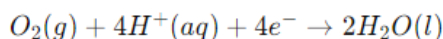
a.

In a water electrolyser system, hydrogen gas (H_2) is produced at the cathode (1 mark). The balanced half equation for the reaction at the cathode is

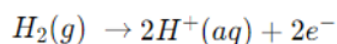


b.

At cathode: (1 mark)



At anode:



c.

Green hydrogen is hydrogen gas that is produced through the **electrolysis of water** using **renewable energy** sources such as wind, solar, or hydroelectric power. (1 mark)

Advantage (1 mark for any one of the following)

- As this production method does not emit greenhouse gases, green hydrogen is considered a sustainable and environmentally friendly energy carrier.
- Green hydrogen does not produce polluting gases during combustion or production.
- It only releases water vapor when used as a fuel, which helps in reducing greenhouse gas emissions.

Challenges (1 mark for any one)

- The electrolysis process required to produce green hydrogen is energy-intensive
- Production of green H₂ is more expensive compared to traditional hydrogen production methods from fossil fuels.
- Limited infrastructure exists for production, storage, and distribution of green hydrogen

d. Hydrogen fuel cells offer clean energy conversion, producing only water as a byproduct (1 mark). They are particularly effective when combined with renewable sources like solar PV to generate green hydrogen, enhancing overall sustainability of the energy system (1 mark).

The sustainability of hydrogen fuel cells largely depends on the source of the hydrogen. If produced using renewable energy, it represents a sustainable option (1 mark). However, if fossil fuels are used for hydrogen production, it diminishes the environmental benefits and may not be sustainable (1 mark)

e.

Hydrogen compressors are crucial for storing hydrogen gas efficiently due to its very low density at standard atmospheric pressure. (1 mark)

Compressing hydrogen reduces its volume, making it feasible to store larger quantities in smaller, more manageable volumes. (1 mark)

Question 5

a.

Carbonyl group or C=O

b.

Three carbon environments (1 mark) as there are three signals in p ¹³C-NMR spectrum (1 mark)

c.

Three hydrogen environments (1 mark) as there are three signals in proton NMR spectrum (1 mark)

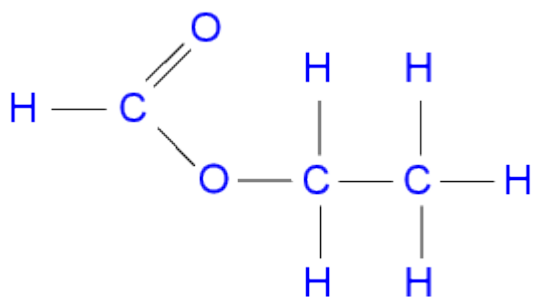
d.

Two

e.

The organic compound is not an acid

f.



1 mark for correct name,

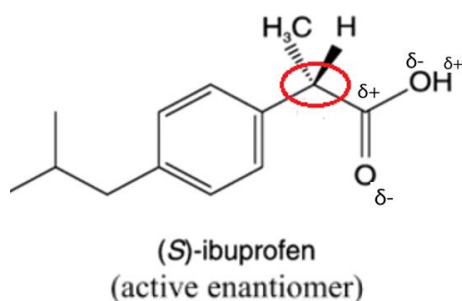
1 mark for correct structural formula.

Systematic name: Ethyl methanoate

Question 6

a.

A chiral center in a molecule is an atom that has four different groups or atoms attached to it, resulting in non-superimposable mirror images. (1 mark) second mark for correct circle.



b. 1 mark for each correctly labelled partial charges shown on active (S) enantiomer.

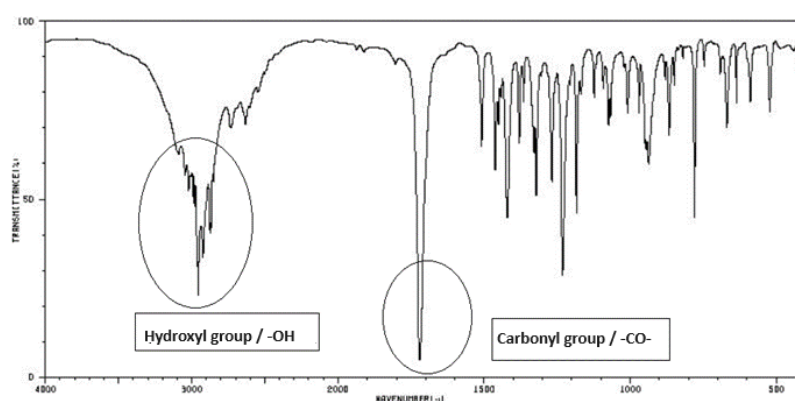
c.

Even though both enantiomers have the same molecular formula and sequence of bonded atoms, their three-dimensional orientations are different, as they are mirror images that cannot be superimposed (1 mark).

This difference in orientation affects how each enantiomer interacts with molecular targets in the body, such as enzymes (1 mark)

The S enantiomer of ibuprofen fits well into the active site of the enzyme and is active. The R enantiomer, however, does not align properly within the active site, resulting in its inability to bind effectively and hence is inactive (1 mark)

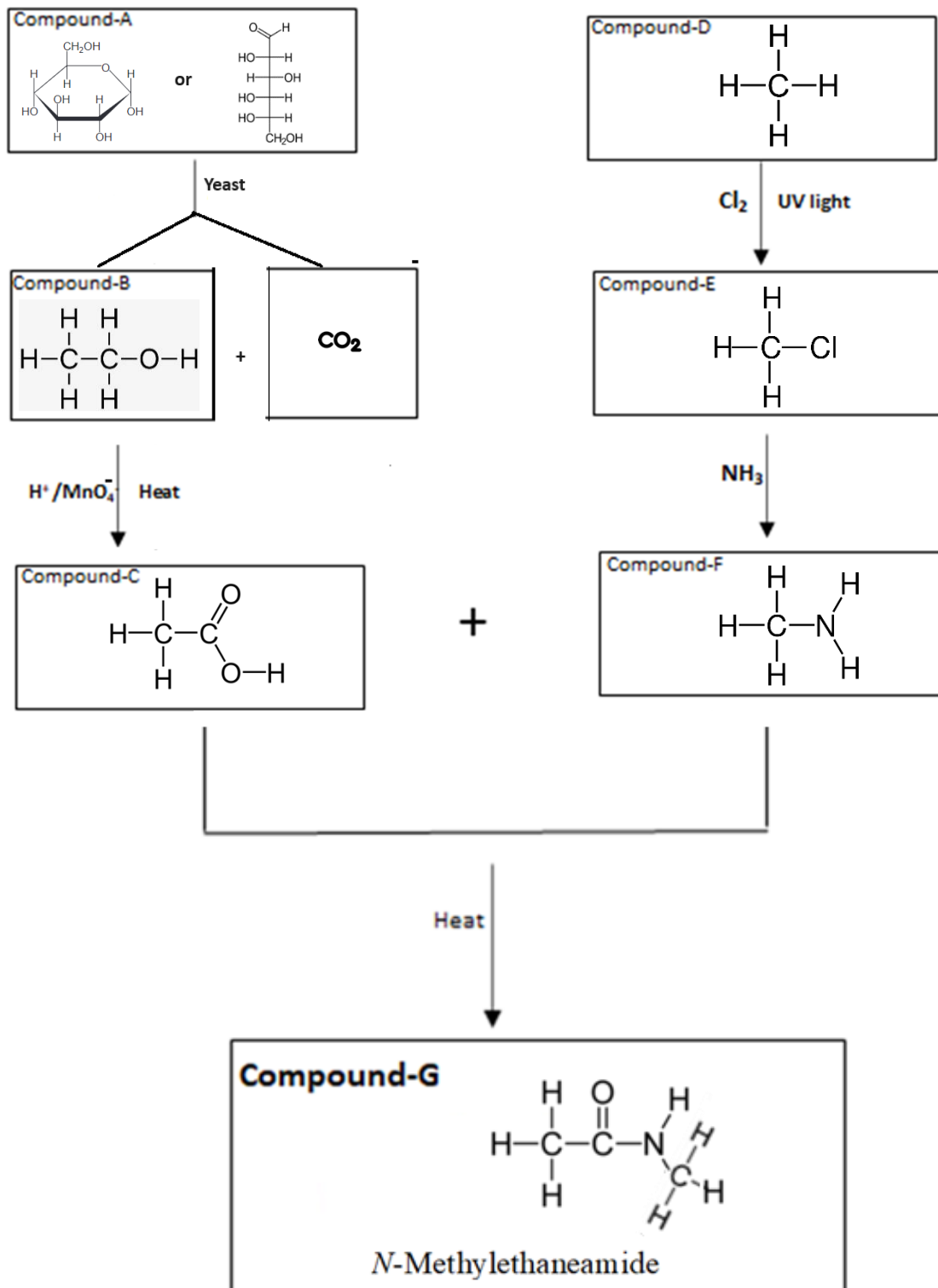
d. 1 mark for each correct functional group name or formula



e.

Ethanol is less polar than water as it possesses both a polar hydroxyl group and a nonpolar ethyl group (1 mark). The nonpolar part of ethanol can interact favorably with the larger nonpolar group of ibuprofen, facilitating better solubility in ethanol compared to water (1 mark)

Question 7



Question 8**a.**

Green fuels are energy sources that are created from environmentally friendly processes and resources and are carbon neutral. (1 mark)

Examples of green fuels include: (Any two of the following, 1+1 mark)

Biofuels: Produced from organic materials or biomass, such as plants, agricultural waste, or algae. They release less pollution than traditional fossil fuels

Green Hydrogen: Hydrogen fuel that is produced using renewable energy sources through processes like water electrolysis. When used, it emits only water vapor, making it an environmentally friendly option.

Green Ammonia: Ammonia produced using hydrogen derived from renewable energy sources, combined with nitrogen from the air. It is considered green when the energy used in its production is sourced from renewable methods. It does not produce any carbon based by product when combusted.

(Accept any other reason example, like biodiesel, bioethanol etc)

b.

(1 mark for identifying, 1 mark for correct explanation)

1. **Low temperature:** The reaction is exothermic (ΔH is negative, indicating heat is released). According to Le Chatelier's principle, lowering the temperature favors the exothermic reaction, thereby increasing the yield of ammonia. However, very low temperatures can also significantly slow down the reaction rate. Therefore, a compromise temperature is used in.
2. **High pressure:** Increasing the pressure favors the formation of ammonia because the forward reaction results in a decrease in the number of gas molecules (from 4 moles of reactants to 2 moles of products). According to Le Chatelier's principle, increasing pressure shifts the equilibrium towards the side with fewer gas molecules.

Question 9

a.

independent variable: temperature (of permanganate solution) (1 mark)

dependent variable: time taken (for potassium permanganate solution/mixture) to decolourise (1 mark)

b.

Increasing the temperature will decrease the time taken for the acidified potassium permanganate to decolourise (change from purple to pale pink/colourless), as the rate of reaction increases with increasing temperature. (2 marks)

c.

Systematic errors produce consistently high or consistently low measurements compared to the true value (1 mark)

- Example of a systematic error in this experiment is (1 mark for any one of the following)
 - only heating one solution
 - using an inappropriate proportion of reactants due to measurement inaccuracies of the syringe.
 - errors in calibration with equipment
 - inappropriate rinsing of glassware

Random errors reduce the closeness in the measurements that can be either high or low/fluctuate around the true value (1 mark)

Example of a random error in this experiment is (1 mark for any of the following)
Any one of:

- parallax (reading of meniscus on the syringe)
- stopping the stopwatch when the solution discolours
- reading thermometer
- not using the same measuring equipment during the reaction
- using measuring cylinder rather than pipette

Accept any other relevant example of random/systematic errors

d.

In a chemistry investigation, repeatability and reproducibility are both important concepts that describe the reliability and precision of experimental results, but they refer to different aspects of the experimental process

Repeatability refers to the closeness of the agreement between the results of successive measurements under identical conditions, i.e. performed by the same researcher in the same laboratory under same conditions. (1 mark), Repeatability can be used to evaluate the quality of data in terms of the precision of measurement results (1 mark).

Reproducibility, on the other hand, refers to the closeness of the agreement between the results of measurements of the same quantity being measured, carried out under changed conditions of measurement (1 mark). Reproducibility is used to evaluate the quality of data in terms of both precision and accuracy of measurement results (1 mark).

Question 10

a.

Petrodiesel is primarily composed of hydrocarbons, obtained through the fractional distillation of crude oil. Biodiesel, on the other hand, consists of long-chain fatty acid methyl esters, specifically produced through the transesterification of vegetable oils or animal fats (1 mark). Renewable diesel, while using the same biomass feedstock as biodiesel, undergoes different processing methods such as hydrotreatment. This process removes oxygen, resulting in a chemical structure very similar to that of petrodiesel, producing hydrocarbons identical to those found in conventional diesel fuels (1 mark).

In terms of physical properties, biodiesel exhibits a higher viscosity than petrodiesel (1 mark), which impacts its flow through fuel lines and filters. It also has a lower energy density, which means it generates less energy per unit volume than petrodiesel or renewable diesel (1 mark).

b.

The production and utilisation of biodiesel and renewable diesel offer significant contributions towards achieving sustainable development goals, presenting substantial improvements over traditional petrodiesel in numerous critical aspects. In terms of environmental impact, both biodiesel and renewable diesel generate fewer greenhouse gas emissions (1 mark). Biodiesel, which is derived from biological sources such as vegetable oils, boasts a smaller carbon footprint. Similarly, renewable diesel, despite being chemically similar to petrodiesel, is produced from renewable sources and exhibits a 50% better environmental performance compared to traditional petrodiesel (1 mark)

Both biofuels are considered more sustainable options than petrodiesel. Biodiesel is biodegradable and non-toxic, contributing to a cleaner environment (1 mark). Renewable diesel, similarly, uses waste and residues as feedstocks, thus promoting waste reduction and resource efficiency (1 mark)