1)

Ethanol is soluble in water. The **best** explanation for this is

☒ **A** ethanol molecules form hydrogen bonds with water molecules.

☒ **B** ethanol molecules form London (dispersion) forces with water molecules.

☒ **C** ethanol molecules form permanent dipole interactions with water molecules.

☒ **D** ethanol and water are miscible liquids.

(Total for Question = 1 mark)

2)

During a titration, when the solution in a pipette is transferred to a conical flask, a small amount of liquid remains in the tip of the pipette. This situation should be dealt with by

☒ **A** leaving the liquid in the pipette which is calibrated to allow for it.

☒ **B** slightly over-filling the pipette to compensate for the additional volume.

☒ **C** carefully blowing the liquid out of the pipette to ensure that it is empty.

☒ **D** repeating the titration.

(Total for Question = 1 mark)

3)

The tolerance of a 25 cm^3 pipette is ±0.06 cm^3. The percentage error in the measurement of 25 cm^3 using this pipette is

☒ **A** ±0.06%

☒ **B** ±0.12%

☒ **C** ±0.24%

☒ **D** ±0.48%

(Total for Question = 1 mark)

4)

A series of titrations is carried out using the same conical flask. Before carrying out each titration, the conical flask **must** be

☒ **A** rinsed with ethanol.

☒ **B** rinsed with distilled or deionised water.

☒ **C** rinsed with the solution that it will contain.

☒ **D** dried to remove all traces of liquid.

(Total for Question = 1 mark)

5)
When excess calcium is added to water, effervescence occurs and

☐ **A** a clear colourless solution is formed.

☐ **B** a cloudy suspension is formed.

☐ **C** an orange-red flame is seen.

☐ **D** a yellow flame is seen.

(Total for Question = 1 mark)

6)
When samples of magnesium nitrate, $Mg(NO_3)_2$, and calcium nitrate, $Ca(NO_3)_2$, are heated

☒ **A** both compounds decompose to form the corresponding nitrite and oxygen.

☒ **B** both compounds decompose to form the corresponding oxide, nitrogen dioxide and oxygen.

☒ **C** magnesium nitrate decomposes to form magnesium nitrite and oxygen whereas calcium nitrate decomposes to form calcium oxide, nitrogen dioxide and oxygen.

☒ **D** magnesium nitrate decomposes to form magnesium oxide, nitrogen dioxide and oxygen whereas calcium nitrate decomposes to form calcium nitrite and oxygen.

(Total for Question = 1 mark)

7)
Which of the following is a secondary alcohol?

☐ **A** butan-1-ol

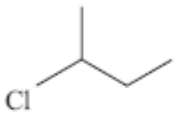
☐ **B** butan-2-ol

☐ **C** 2-methylpropan-1-ol

☐ **D** 2-methylpropan-2-ol

(Total for Question = 1 mark)

8)
The compound



has the systematic name

☒ **A** 2-chlorobutane

☒ **B** 3-chlorobutane

☒ **C** 1-chloro-1-methylpropane

☒ **D** 1-chloro-2-methylbutane

(Total for Question = 1 mark)

9)
When a chloroalkane is heated with aqueous sodium hydroxide

☐ **A** no reaction occurs with primary, secondary or tertiary chloroalkanes.

☐ **B** a reaction occurs with primary and secondary chloroalkanes but not with tertiary chloroalkanes.

☐ **C** a reaction occurs with tertiary chloroalkanes but not with primary and secondary chloroalkanes.

☐ **D** a reaction occurs with primary, secondary and tertiary chloroalkanes.

(Total for Question = 1 mark)

10)
Brown nitrogen dioxide, NO_2, exists in equilibrium with colourless dinitrogen tetroxide, N_2O_4.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \quad \Delta H = -57.2 \text{ kJ mol}^{-1}$$
brown colourless

(a) The **pressure** is increased. When equilibrium is restored, the appearance of the mixture of gases will be

(1)

☐ **A** colourless.

☐ **B** unchanged.

☐ **C** paler brown.

☐ **D** darker brown.

(b) The **temperature** is increased. When equilibrium is restored, the appearance of the mixture of gases will be

(1)

☐ **A** colourless.

☐ **B** unchanged.

☐ **C** paler brown.

☐ **D** darker brown.

(Total for Question = 2 marks)

11)
When propanal, CH_3CH_2CHO, and propanone, CH_3COCH_3, are compared using physical methods of analysis, which of the following is **not** correct?

☐ **A** The carbonyl groups absorb at very similar frequencies of the IR spectrum.

☐ **B** The compounds will have different patterns in the fingerprint region of the IR spectrum.

☐ **C** The compounds will form different fragmentation patterns in a mass spectrum.

☐ **D** The compounds will have molecular ion peaks at different mass to charge ratios in a mass spectrum.

(Total for Question = 1 mark)

12)

Chlorine disinfectants are essentially solutions containing chlorine molecules and chlorate(I) ions in an equilibrium summarised by the equation

$$Cl_2(aq) + H_2O(l) \rightleftharpoons 2H^+(aq) + ClO^-(aq) + Cl^-(aq) \qquad \textbf{Equation 1}$$

The chlorine content of a disinfectant was determined using the following procedure.

1. 10.0 cm^3 of the disinfectant was transferred to a 250 cm^3 volumetric flask.

2. Approximately 20 cm^3 of nitric acid and 20 cm^3 potassium iodide solution (both in excess) were added to the volumetric flask.

3. The solution in the volumetric flask was made up to the mark with distilled water and then mixed thoroughly.

4. 10.0 cm^3 portions of the solution in the volumetric flask were titrated against a solution of sodium thiosulfate, concentration 0.109 mol dm^{-3}. Starch solution was added near the end-point of the titration and the mean (average) titre was 27.35 cm^3.

The equations for the reactions involved in this procedure are

$$Cl_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq) \qquad \textbf{Equation 2}$$

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq) \qquad \textbf{Equation 3}$$

(a) (i) Calculate the number of moles of sodium thiosulfate used in the titration.

(2)

(ii) Calculate the number of moles of iodine, I_2, that reacted in the titration (step 4).

(1)

(iii) Hence state the number of moles of chlorine, Cl_2, in 10.0 cm^3 of the solution in the volumetric flask. (1)

(iv) Calculate the concentration of chlorine, in mol dm^{-3}, in the **original** disinfectant.

(2)

(b) **Equation 1** is an example of a disproportionation reaction. Define the term 'disproportionation' and explain, by considering the relevant oxidation numbers, why this reaction is a disproportionation.

(3)

(c) State the colours of the titration solution just before the starch solution is added, after the starch solution is added and the colour change at the end-point of the reaction.

(2)

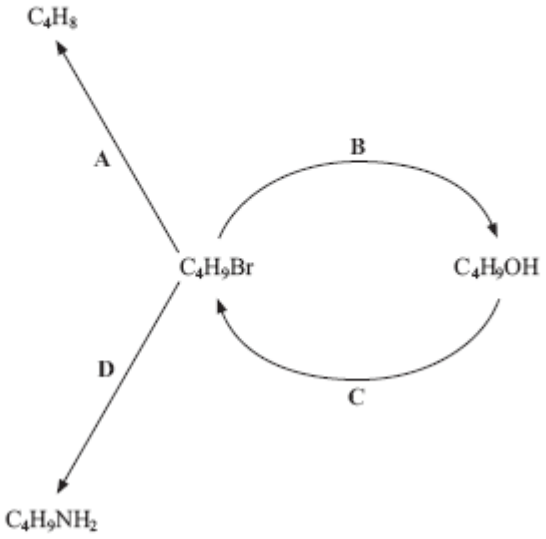
Colour just before adding the starch .....

Colour after adding the starch .....

Colour at the end-point .....

13)

Halogenoalkanes are important intermediates in organic chemistry. The scheme below summarises some important reactions of a halogenoalkane.



(a) Identify the reagents and any specific conditions required for the reactions in the diagram. (You may assume that a suitable temperature is maintained in each reaction.)

(4)

A .....

B .....

C .....

D .....

(b) (i) Classify the type of reaction in each of **A** and **D**.

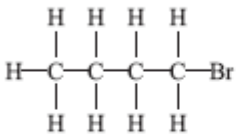
(2)

A .....

D .....

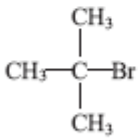
*(ii) Reaction **B** can proceed via two possible reaction mechanisms, depending on the structure of the original compound. For each of the two isomers of C_4H_9Br shown below, draw the structure of the intermediate or transition state which is formed during the reaction. Explain in each case why the specified structure is more favourable.

(4)



Intermediate or transition state

Explanation .....



Intermediate or transition state

Explanation .....

(iii) If C_4H_9I is used instead of C_4H_9Br in reaction **D**, the rate of formation of $C_4H_9NH_2$ increases. Explain why the rate of reaction increases.

(1)

(c) Halogenoalkanes are widely used as refrigerants and belong to the class of refrigerants that cool by change of state (typically by boiling).

(i) Suggest how halogenoalkanes cool by change of state.

(1)

(ii) Suggest **two** characteristics or properties desirable in a refrigerant.

(2)

14)

Nitrogen monoxide is an unusual molecule both in its chemical structure (shown below) and in its impact on our lives.

Nitrogen monoxide is an important chemical messenger in all mammals and, at appropriate concentrations, it is vital to life; however, at high concentrations in the body, it is extremely toxic.

Nitrogen monoxide is considered a dangerous atmospheric pollutant; it is involved in the formation of a range of toxic substances, including ozone, at low altitudes, and in the depletion of the ozone layer at high altitudes.

Nitrogen monoxide is formed by the direct combination of nitrogen and oxygen at high temperatures, a reaction that occurs naturally in lightning discharges, and as a by-product of the reactions in internal combustion and jet engines. Catalytic converters reduce nitrogen monoxide emissions from car engines by catalysing the reaction between nitrogen monoxide and carbon monoxide to form nitrogen and carbon dioxide.

The reactions of nitrogen monoxide which involve ozone in the atmosphere are summarised below.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

$$NO_2(g) \xrightarrow{\text{UV radiation}} NO(g) + O(g)$$

$$O_2(g) + O(g) \longrightarrow O_3(g)$$

$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

When the ratio of nitrogen dioxide to nitrogen monoxide is high (> 3), the rate of formation of ozone is faster than its rate of removal. When the ratio is low (< 0.3), the reverse is true.

Ozone causes breathing difficulties, headaches, fatigue and can aggravate respiratory problems. The reaction of nitrogen monoxide with hydrocarbons can also produce other toxic compounds, such as aldehydes.

(a) Write the equation for the formation of nitrogen monoxide from nitrogen and oxygen. State symbols are **not** required.

(1)

(b) The electronic structure of nitrogen monoxide is unusual in that it has an unpaired electron.

(i) What name is given to a chemical species such as nitrogen monoxide that has an unpaired electron?

(1)

(ii) Chemical species with unpaired electrons occur as intermediates in some chemical reactions. What type of bond breaking produces these species?

(1)

(c) (i) Suggest the most likely source of the hydrocarbons that react with nitrogen monoxide to form toxic compounds.

(1)

(ii) Suggest the type of reaction that is involved when a hydrocarbon is converted into an aldehyde.

(1)

(iii) Draw the **skeletal** formula of the aldehyde with three carbon atoms.

(1)

(iv) By considering the equation

$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g)$$

explain the effect of the reaction of hydrocarbons with nitrogen monoxide on the breakdown of ozone.

(1)

(d) Suggest why the proportion of nitrogen dioxide might be reduced at high altitudes.

(2)

(e) Explain why it is important to maintain the concentration of ozone in the upper atmosphere.

(2)

(f) (i) Write an equation for the reaction on a catalytic converter described in the passage. State symbols are **not** required.

(1)

(ii) Draw an energy profile for the exothermic reaction in (f)(i). Label the axes, the reactants and products, the enthalpy change and the activation energy.

(3)

*(iii) By referring to your energy profile, explain how a catalyst speeds up a chemical reaction.

(3)

(g) Jet aircraft are considered a greater threat to the ozone layer than road vehicles. Suggest an explanation for this.

(2)

15)

The systematic name of the compound with skeletal formula shown above is

☐ **A** 1,1-dimethylethanol.

☐ **B** 2,2-dimethylethanol.

☐ **C** 2-methylpropan-1-ol.

☐ **D** 2-methylpropan-2-ol.

(Total for Question = 1 mark)

16)

12 Samples of 1-chloropropane and 1-bromopropane are warmed with water containing dissolved silver nitrate in the presence of ethanol. The 1-chloropropane reacts more slowly because

☐ **A** the C—Cl bond is more polar than the C—Br bond.

☐ **B** the C—Cl bond is stronger than the C—Br bond.

☐ **C** 1-chloropropane is less soluble than 1-bromopropane.

☐ **D** 1-chloropropane is a weaker oxidizing agent than 1-bromopropane.

(Total for Question = 1 mark)

17)

The reaction of 1-chloropropane with water containing dissolved silver nitrate in the presence of ethanol is

☐ **A** a redox reaction.

☐ **B** a nucleophilic substitution.

☐ **C** an electrophilic substitution.

☐ **D** a free radical substitution.

(Total for Question = 1 mark)

18)

The compound with formula $CH_3CH(NH_2)CH_3$ can be made by reacting alcoholic ammonia with

☐ **A** propane.

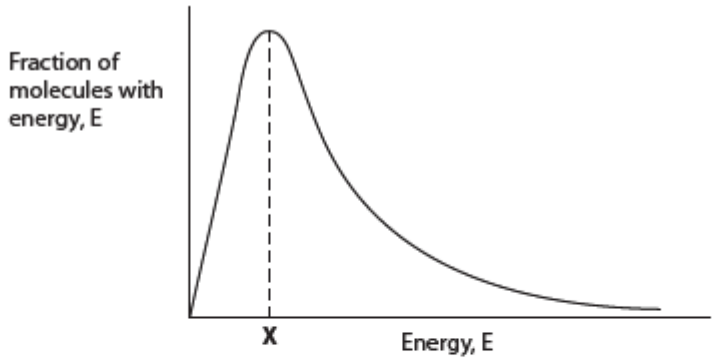
☐ **B** propene.

☐ **C** 2-chloropropane.

☐ **D** propan-2-ol.

(Total for Question = 1 mark)

19)



The energy marked **X** in the Maxwell-Boltzmann distribution shows

☐ **A** the most common energy of the molecules.

☐ **B** the activation energy of the reaction.

☐ **C** the activation energy of a catalysed reaction.

☐ **D** the number of molecules with energy greater than the activation energy.

(Total for Question = 1 mark)

20)

In the industrial process involving gas phase reactions to produce ammonia, many collisions between molecules are unsuccessful because

☐ **A** gas phase reactions are reversible.

☐ **B** the collisions are not energetic enough to break the bonds in the molecules.

☐ **C** gas phase reactions can only occur when a catalyst is present.

☐ **D** gas phase reactions can only occur when UV light is present.

(Total for Question = 1 mark)

21)

The molecular (parent) ion in the mass spectrum of a hydrocarbon containing ^{12}C and ^{1}H only

☐ **A** is the peak with highest relative abundance.

☐ **B** is the peak with highest charge.

☐ **C** is the peak produced by the most stable fragment.

☐ **D** is the peak with highest mass to charge ratio.

(Total for Question = 1 mark)

22)

A compound which has major peaks with mass / charge ratio at 29, 57 and 58 in the mass spectrum could be

☐ **A** propanal, CH_3CH_2CHO.

☐ **B** propanone, CH_3COCH_3.

☐ **C** propan-1-ol, $CH_3CH_2CH_2OH$.

☐ **D** propan-2-ol, $CH_3CH(OH)CH_3$.

(Total for Question = 1 mark)

23)

Which of the following would **not** be used to assess whether the use of a biofuel produced from a crop of sugar cane is carbon neutral?

The amount of

☐ **A** fuel used to operate farm machinery.

☐ **B** pesticides and fertilisers used.

☐ **C** energy released per tonne of biofuel.

☐ **D** fuel used to process the crop.

(Total for Question = 1 mark)

24)

The principal reason why scientists have recommended that chlorofluorocarbons (CFCs) are not used in aerosols is that they cause

☐ **A** global warming.

☐ **B** acid rain.

☐ **C** ozone depletion.

☐ **D** water pollution.

(Total for Question = 1 mark)

25)

(a) The products of the reaction when 2-chlorobutane is heated with sodium hydroxide depend on the conditions.

(i) What condition, other than a suitable temperature and sodium hydroxide concentration, would produce a mixture of but-1-ene and but-2-ene?

(1)

.....

(ii) What type of reaction occurs in (a)(i)?

(1)

.....

(iii) What condition, other than a suitable temperature and sodium hydroxide concentration, would produce butan-2-ol in the reaction of 2-chlorobutane with sodium hydroxide?

(1)

.....

(iv) Suggest the mechanism for the reaction of 2-chlorobutane with hydroxide ions to form butan-2-ol. Use curly arrows to show the movement of electron pairs.

(2)

(b) Phosphorus(V) chloride, PCl_5, can be used to test for the –OH group.

Describe what would be seen when phosphorus(V) chloride is added to butan-2-ol. Give the equation for the reaction. State symbols are not required.

(2)

Observation .....

Equation

(c) A tertiary alcohol, **A**, is an isomer of butan-2-ol.

(i) Butan-2-ol and **A** can be distinguished by warming separate samples with a mixture of potassium dichromate(VI) and sulfuric acid. State the observations which would be made with each alcohol.

(2)

Observation with butan-2-ol .....

.....

Observation with **A** .....

.....

(ii) Give the structural formula of the organic product which forms when butan-2-ol is oxidized.

(1)

(iii) Explain how infrared spectroscopy could be used to detect whether butan-2-ol has been oxidized.

(1)