IB · DP · Chemistry

2 hours 11 questions

Practice Paper 2

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Total Marks **/90**

1 (a) Ammonia, NH_3, is a chemical that is key in the manufacture of certain fertilisers and cleaning products.

An ammonia molecule will react with an H^+ ion, to form the ammonium ion, NH_4^+.

Draw a Lewis (electron dot) diagram to show the bonding in the ammonium ion and name the type of bond formed between the ammonia molecule and the hydrogen ion.

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(2 marks)

(b) Lewis (electron dot diagrams) are used to show the electron arrangement in the valence shells of covalently bonded molecules.

Draw Lewis diagrams for the following molecules:

(i) Hydrogen cyanide.

(ii) Carbon dioxide.

(iii) Boron trifluoride.

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(3 marks)

(c) Using your answer to part (b), identify and explain the species that is likely to form a coordinate covalent bond.

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(2 marks)

(d) Using your answer to part (c), Explain, with the help of a diagram, the covalent bond formed between the species in part (c) and ammonia.

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(3 marks)

2 (a) Aluminium will react with copper(II) sulfate solution according to the following equation:

$$2Al\ (s) + 3CuSO_4\ (aq)\ "\ \ 3Cu\ (s) + Al_2(SO_4)_3\ (aq)$$

The reaction is quite slow at room temperature, but when chloride ions in the form of hydrochloric acid are added, the rate increases significantly. The chloride ions catalyse the reaction.

An experiment was carried out to determine the yield of the reaction. A student made a solution of aqueous copper(II) sulfate by dissolving 2.00 g of copper(II) sulfate pentahydrate, $CuSO_4.5H_2O$ (M_r 249.72 g mol^{-1}) in 10.0 mL of distilled water in a small beaker.

To this solution she added 0.25 g of aluminium foil followed by 2.0 mL of 6.0 mol dm^{-3} hydrochloric acid.

After the reaction was complete, she collected, dried, and weighed the copper that was produced.

She recorded the measurements in **Table 1** below.

Table 1

	Mass / ± 0.01 g
Initial mass of copper sulfate	2.00
Mass of aluminium foil used	0.25
Mass of empty beaker	42.18
Mass of beaker with dry copper	42.61

Use the data to show that the copper sulfate is the limiting reagent in the experiment and calculate the mass of aluminium in excess.

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(4 marks)

(b) Calculate the actual yield and the percentage yield of copper in the experiment.

(3 marks)

(c) Determine the percentage uncertainty in the mass of copper produced, and the overall percentage error for the experiment.

(2 marks)

(d) Discuss the impact on the percentage yield of copper from the following systematic errors:

i) The copper collected is not fully dried out before the beaker is weighed.

ii) The student misread the instructions and used 1.0 mL of hydrochloric acid.

(2 marks)

3 (a) The decomposition of hydrogen peroxide into water and oxygen is a very slow chemical reaction.

Write the equation for the decomposition of hydrogen peroxide.

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(1 mark)

(b) The rate of decomposition of hydrogen peroxide can be found by collecting and measuring the volume of gas formed at specific time intervals.

i) Draw a labelled diagram to show the apparatus that you would use to collect and measure the volume of gas formed during this reaction.

ii) Explain how you would use the results to determine the initial rate of the reaction.

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(5 marks)

(c) The decomposition of hydrogen peroxide is a slow reaction, so a catalyst is often added to speed up the rate of the reaction. Catalysts are used in many chemical reactions to increase the rate.

The following shows a two-step reaction mechanism of a chemical reaction, where a catalyst, **X** is used.

STEP 1: $W + X \rightarrow Y + Z$

STEP 2: $Y + W \rightarrow Z + A + X$

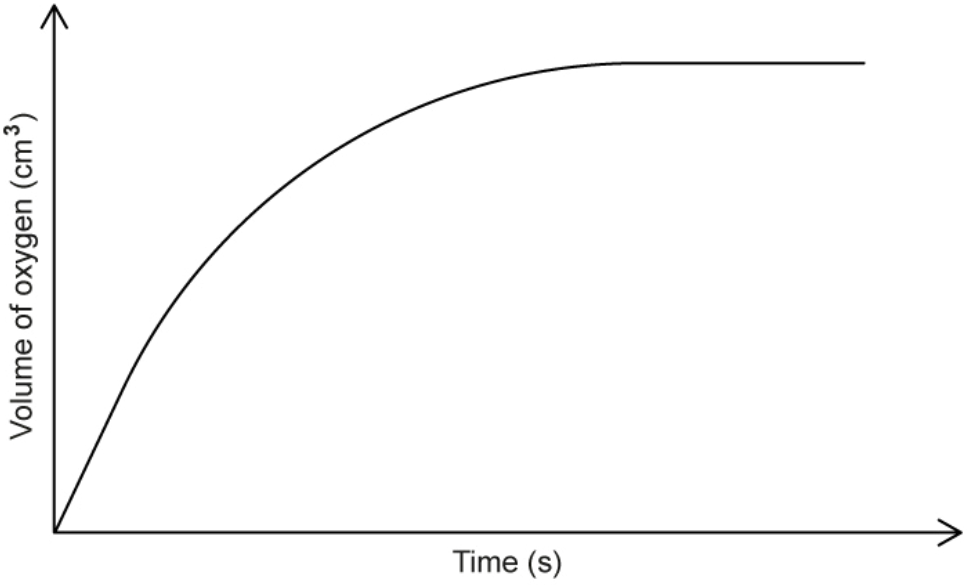
OVERALL REACTION: $2W \rightarrow 2Z + A$

Give a reason, other than the rate of reaction increasing, why it can be deduced from the three equations above that X is a catalyst.

(1 mark)

(d) The graph shown below represents the decomposition of hydrogen peroxide.

Figure 1



The graph starts to level out as the reaction slows down.

State why the rate of the reaction slows down over time.

(1 mark)

4 (a) For the reaction below, consider the following experimental data.

$$X\ (aq) + Y\ (aq) \rightarrow Z\ (aq)$$

Experiment	Initial [X] / mol dm^{-3}	Initial [Y] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.030	0.040	4.0×10^{-4}
2	0.045	0.040	6.0×10^{-4}
3	0.060	0.120	2.4×10^{-3}

Deduce the order of reaction with respect to X.

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(2 marks)

(b) Deduce the order of the reaction with respect to Y.

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(2 marks)

(c) Write the rate expression for the reaction between X and Y.

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(1 mark)

(d) Determine the rate constant, *k*, correct to three significant figures and state its units, using data from Experiment 2.

Experiment	Initial [X] / mol dm^{-3}	Initial [Y] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.030	0.040	4.0×10^{-4}
2	0.045	0.040	6.0×10^{-4}
3	0.060	0.120	2.4×10^{-3}

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(3 marks)

5 (a) Astronauts on the Apollo 13 Mission in 1970 avoided disaster by making use of lithium hydroxide canisters, to absorb waste carbon dioxide in their spacecraft through a chemical reaction. The reaction produces lithium carbonate and water as the only products.

(i) Write a balanced equation for the reaction between lithium hydroxide and carbon dioxide.

(ii) Determine the mass, in kg, of carbon dioxide absorbed by 4.00 kg of lithium hydroxide.

(4 marks)

(b) Calculate the percentage yield of lithium carbonate if 5.00 g of lithium hydroxide produces 6.76 g of lithium carbonate.

(2 marks)

(c) Determine the maximum volume, in dm^3, of carbon dioxide at 293 K and 100 kPa that can be absorbed by 125.0 g of lithium hydroxide.

(2 marks)

6 (a) Phosphorus tribromide and sulfur tetrafluoride are two colourless compounds which both react with water to form toxic products.

Deduce the Lewis(electron dot) structure of both molecules.

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(2 marks)

(b) Predict the shapes of the two molecules of phosphorus tribromide and sulfur tetrafluoride

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(2 marks)

(c) Explain why both phosphorus tribromide and sulfur tetrafluoride are polar.

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(2 marks)

7 (a) Dichloromethyl benzene reacts with chlorine to produce trichloromethyl benzene. State the name of this type of menchanism and the required condition.

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(2 marks)

(b) Outline the mechanism for the reaction occurring in part a).

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(4 marks)

(c) A reaction pathway is shown below. Compound **J** reacts with bromine water to form a colourless solution.

State the IUPAC name for Compound J.

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(1 mark)

(d) Identify the reagents and conditions for the formation of Compound Y from Compound J.

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(2 marks)

8 (a) A student is asked to prepare a sample of propyl propanoate using propanal.

Suggest a reaction scheme, using displayed formulae, that the student could use to prepare their sample of propyl propanoate.

Conditions and reagents are not required.

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(2 marks)

(b) Use your answer from part (a) to help answer this question.

One of the intermediates in the reaction scheme, from part (a), has a molecular mass of 74.0 g mol^{-1}.

Give the reagents and conditions required to form this intermediate.

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(1 mark)

(c) Propanal and the other intermediate (M_r = 60.0) in the reaction scheme, from part (a), are to be separated by distillation.

Explain which chemical will distil first.

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(2 marks)

(d) Use your answer from part (a) to help answer this question.

Consider the intermediate in the reaction scheme, from part(a), which has a molecular mass of 60.0 g mol^{-1}.

i) Give the reagents and conditions required to form this intermediate.

[3]

ii) Describe how you could prove that this intermediate has been formed **without** reversing the reaction using section 26 of the data booklet.

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(4 marks)

9 (a) State what is meant by the term *dynamic equilibrium*.

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(1 mark)

(b) Describe **two** characteristics of a reaction at equilibrium.

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(2 marks)

(c) Methanoic acid reacts with methanol to form the ester methyl methanoate.

$$HCOOH\ (l) + CH_3OH\ (l) \rightleftharpoons HCOOCH_3\ (l) + H_2O\ (l)$$

The esterification reaction is exothermic. State the effect of increasing temperature on the value of the equilibrium constant (K_c) for this reaction.

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(1 mark)

10 (a) Use section 24 of the data booklet to draw the electrochemical cell for the feasible reaction of Ag / Ag^{+} and Al / Al^{3+}. Write the conventional representation, including state symbols, for this cell.

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(3 marks)

(b) Write the conventional representation, including state symbols, for this cell.

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(1 mark)

(c) Explain why the salt bridge connecting the silver and aluminum electrodes cannot be made with potassium chloride solution.

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(2 marks)

(d) The silver half cell is replaced with a magnesium half cell. Deduce the reading on the voltmeter.

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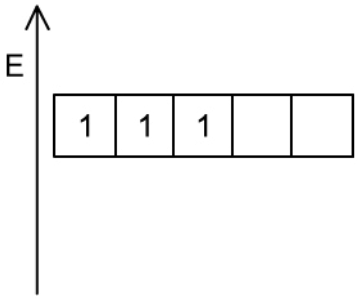
(2 marks)

11 (a) The energy level diagram showing the electrons in the five 3d orbitals of a chromium atom is shown in the figure below.

Draw the completed diagram showing the d orbitals in $[Cr(H_2O)_6]^{3+}$ after splitting.



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(1 mark)

(b) State and explain what happens to the splitting of the d orbitals if the ligand is changed from H_2O to NH_3.

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(2 marks)

(c) Explain, in terms of acid-base theories, what type of a reaction is the formation of $[Fe(H_2O)_6]^{2+}$ from Fe^{2+} and water

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(2 marks)

(d) The complex ion $[Ni(NH_3)_6]^{2+}$ is blue and $[Ni(H_2O)_6]^{2+}$ is green

Explain why the $[Ni(H_2O)_6]^{2+}$ complex ion is coloured and outline why changing the identity of the ligand changes the colour of the ion.

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(4 marks)