IB · DP · Chemistry

2 hours 15 questions

Structured Questions: Paper 2

1.2 Reacting Masses & Volumes

1.2.1 Reacting Masses / 1.2.2 Reaction Yields / 1.2.3 Avogadro's Law & Molar Gas Volume / 1.2.4 The Ideal Gas Equation / 1.2.5 Gas Law Relationships / 1.2.6 Real Gases / 1.2.7 Standard Solutions / 1.2.8 Concentration Calculations / 1.2.9 Titrations

Easy (5 questions)	/38
Medium (5 questions)	/41
Hard (5 questions)	/48
Total Marks	**/127**

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Easy Questions

1 (a) In a firework, solid potassium nitrate, KNO_3, decomposes to form solid potassium nitrite, KNO_2, and oxygen, O_2.

(i) Write a balanced symbol equation for this reaction.

(ii) Use section 6 of the data booklet to calculate the amount, in g, of potassium nitrate, KNO_3, required to make 1.5 g of oxygen. Give your answer to 2 significant figures.

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(4 marks)

(b) Use section 2 of the data booklet to calculate the volume of gas at STP, in dm^3, that is produced in the reaction outlined in part (a). Give your answer to 2 significant figures.

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(1 mark)

(c) Potassium can form a superoxide, KO_2 (s), which will react with carbon dioxide, CO_2 (g), to produce potassium carbonate, K_2CO_3 (s) and oxygen, O_2 (g), as shown in the equation below.

$$4KO_2\ (s) + 2CO_2\ (g) \rightarrow 2K_2CO_3\ (s) + 3O_2\ (g)$$

(i) Calculate the amount, in moles, of 5.00 g of potassium superoxide. Give your answer to 3 significant figures

(ii) Calculate the amount, in moles, and therefore volume, in dm^3, of carbon dioxide which will react with the superoxide. Give your answer to 3 significant figures.

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(3 marks)

(d) A student calculated that 4.86 g of potassium carbonate, KCO_3, should be produced during the reaction outlined in part (c), 2.61 g of potassium carbonate, KCO_3, was produced when the experiment was carried out. Calculate the percentage yield for the production of potassium carbonate. Give your answer to 2 decimal places.

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(1 mark)

2 (a) A student carried out a series of titration experiments. Their results from their experiments are shown in the table below.

Titration	Rough	1	2	3
Final reading / cm^3	25.45	21.95	43.65	22.10
Initial reading / cm^3	0.00	0.05	21.90	0.10
Titre / cm^3	25.45	21.90	21.75	22.00

Calculate the mean titre using the concordant results. Give your answer to 2 decimal places.

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(2 marks)

(b) The student added 0.10 mol dm^{-3} hydrochloric acid, HCl (aq), to the burette and performed the titration using a 25.00 cm^3 sample of an unknown carbonate solution. The equation for the neutralisation reaction is shown below.

$$M_2CO_3\,(aq) + 2HCl\,(aq) \rightarrow 2MCl\,(aq) + CO_2\,(g) + H_2O\,(l)$$

(i) Using your answer to part (a), calculate the amount, in moles, of hydrochloric acid used. Give your answer to 2 decimal places.

(ii) Calculate the amount, in moles, of the aqueous carbonate solution. Give your answer to 2 decimal places.

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(2 marks)

(c) Using your answer to part (b) (i) determine the concentration in mol dm^{-3} of the aqueous carbonate. Give your answer to 2 decimal places.

(1 mark)

(d) The student used 1.38 g of the unknown carbonate to make up a 250 cm^3 standard solution for the titration outlined in part (a). Using section 6 of the data booklet, prove that the unknown carbonate is potassium carbonate, K_2CO_3.

Calculate the amount, in moles, of K_2CO_3 .....

Calculate the concentration in, mol dm^{-3}, of K_2CO_3 solution .....

(4 marks)

3.75 g of zinc oxide, ZnO (s), was added to 150 cm^3 of 1.00 mol dm^{-3} of sulfuric acid (aq) producing a salt. Write a balanced symbol equation for this reaction.

3 (a) .....

(1 mark)

Using the equation in part (a) and section 6 of the data booklet, calculate the limiting reagent in the reaction. Give your answer to 2 significant figures.

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(b) .....

(3 marks)

(c) Use your answer to part (b) and section 6 of the data booklet to calculate the amount, in grams, of the salt produced. Give your answer to 3 significant figures.

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(1 mark)

(d) Calculate the amount, in moles, of the excess reactant left over at the end of the reaction. Give your answer to 2 decimal places.

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(1 mark)

4 (a) A sample of pure magnesium nitrate, $Mg(NO_3)_2$, was decomposed by heating as shown in the equation below

$$2Mg(NO_3)_2\,(s) \rightarrow 2MgO\,(s) + 4NO_2\,(g) + O_2\,(g)$$

A 0.75 g sample of $Mg(NO_3)_2$ was completely decomposed by heating.

Calculate the amount, in moles, of magnesium nitrate that was decomposed. Give your answer to 2 decimal places.

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(2 marks)

(b) Calculate the total amount, in moles, of gas produced in the reaction. Give your answer to 2 decimal places.

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(2 marks)

(c) Calculate the total volume, in m^3, of gas produced at 333 K and 100 kPa.

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(2 marks)

5 (a) 90 cm^3 ammonia gas, NH_3 (g), is combusted in oxygen, O_2 (g), to produce nitrogen oxide and water, H_2O (l). What is the total volume of gases remaining when 90 cm^3 of ammonia is combusted completely with 50 cm^3 of oxygen according to the equation shown?

$$4NH_3\,(g) + 5O_2\,(g) \rightarrow 4NO\,(g) + 6H_2O\,(l)$$

Deduce the limiting reagent for the combustion of ammonia, 90 cm^3 ammonia gas, NH_3 (g), is combusted in oxygen.

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(1 mark)

Calculate the total volume, in cm^3, of gases remaining for the reaction in part (a).

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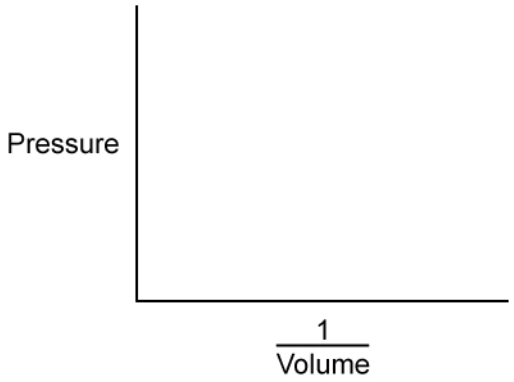
(b) **(4 marks)**

(c) Sketch a line on the graph below that shows the correct relationship between pressure and $\frac{1}{\text{volume}}$



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(1 mark)

(d) At 25 ^{o}C and 100 kPa a gas occupies a volume of 35 dm^3. Using the equation $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, calculate the new temperature, in ^{o}C, of the gas if the volume is decreased to 15 dm^3 at **constant** pressure.

(2 marks)

Medium Questions

1 (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)

(d) When the astronauts on Apollo 13 were solving the problem of excess carbon dioxide in their spacecraft, they had to be careful with their calculations of the volumes of ideal gases.

Explain what is meant by the term *ideal gas* and state the conditions under which carbon dioxide shows deviation from ideal gas behaviour.

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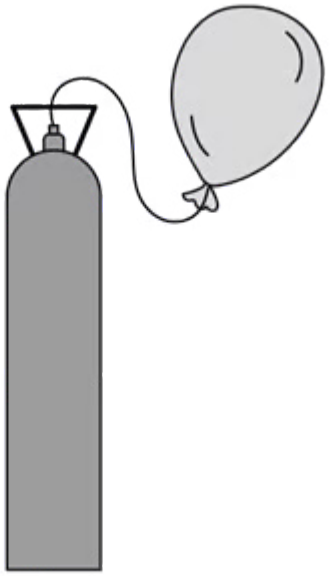
(2 marks)

2 (a) Gas cylinders of helium, like the one shown below, are sometimes used to inflate party balloons.

Figure 1



A typical 11-inch party balloon has a fully inflated volume of 14.1 dm^3. The pressure in the gas cylinders is 20,000 kPa. If the gas cylinder can fill 160 balloons at 298 K and 108 kPa, what is the total volume of helium inside the gas cylinder in dm^3?

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(1 mark)

(b) Sketch a graph to show the relationship between the volume and temperature of an ideal gas at constant pressure. Describe the relationship between the two variables.

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(2 marks)

(c) Deep sea divers sometimes breathe mixtures of helium and oxygen in their scuba diving tanks when the conditions are very deep, so they can avoid nitrogen narcosis.

If a bubble of gas escapes from a scuba tank at 60 m depth where the pressure is 588 kPa and the temperature is 8 ^{o}C, determine the increase in the size of the bubble by the time it reaches the surface where the pressure is 100 kPa and the temperature is 20 ^{o}C.

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(2 marks)

(d) Commercial aircraft are fitted with oxygen cannisters that provide a supply of oxygen in case of the loss of cabin pressure. The cannisters contain sodium chlorate(V) which produces oxygen in the following decomposition reaction.

$$2NaClO_3\,(s)\ "\ 2NaCl\,(s) + 3O_2\,(g)$$

Determine the mass of sodium chlorate(V) needed to produce 10.0 dm^3 of oxygen at 298 K and 90 kPa.

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(4 marks)

3 (a) An analysis of a 2.54 g antacid tablet containing $Mg(OH)_2$ was carried out by titration using 40.00 cm^3 of 1.25 $moldm^{-3}$ sulfuric acid. The acid was in excess.

i) Write an equation for the reaction.

ii) Determine the amount, in mol, of sulfuric acid.

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(2 marks)

(b) The excess sulfuric acid reacted with 21.45 cm^3 of 1.51 $moldm^{-3}$ NaOH.
Determine the amount of excess acid present.

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(2 marks)

(c) Calculate the amount of sulfuric acid that reacted with the $Mg(OH)_2$

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(1 mark)

(d) Determine the mass of $Mg(OH)_2$ that was present in the tablet.

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(1 mark)

(e) Determine the percentage mass of $Mg(OH)_2$ that was present in the tablet.

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(1 mark)

4 (a) Ammonia and nitrogen monoxide react together according to the following equation:

$$4NH_3\,(g) + 6NO\,(g) \rightarrow 5N_2\,(g) + 6H_2O\,(g)$$

50.0 dm^3 of ammonia is reacted with 50.0 dm^3 of nitrogen monoxide at 150.0 ^oC and 100 kPa. Identify the excess reagent and determine the volume of nitrogen produced.

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(2 marks)

(b) Determine the volume of excess gas and hence total volume of gas after the reaction has finished.

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(2 marks)

(c) What mass of nitrogen is produced in the reaction? Express your answer to an appropriate number of significant figures.

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(3 marks)

(d) Explain why calculating the gas volumes in the reaction is likely to be more accurate at 150 ^oC than at room temperature.

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(1 mark)

5 (a) The chlorine level in a swimming pool should lie between 1.0 and 3.0 ppm. Explain the meaning of ppm and express this concentration range in $mol dm^{-3}$.

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(2 marks)

(b) The amount of dissolved chlorine can be analysed by reacting with excess iodide ions under acidic conditions, and titrating the liberated iodine against standard sodium thiosulfate solution in a two-step process:

$$Cl_2(aq) + 2I^-(aq) \text{ " } 2Cl^-(aq) + I_2(aq)$$

$$I_2(aq) + 2S_2O_3^{2-}(aq) \text{ " } 2I^-(aq) + S_4O_6^{2-}(aq)$$

A 25.0 mL sample of chlorine water was analysed and the volume of 0.120 $mol dm^{-3}$ sodium thiosulfate solution, $Na_2S_2O_3$, needed to react with the iodine was recorded in **Table 1**.

Table 1

Volume of $Na_2S_2O_3$	**I**	**II**	**III**
Initial burette reading / *mL* ± 0.05	1.05	23.40	2.10
Final burette reading / *mL* ± 0.05	23.40	45.70	24.50
Titre / *mL*			

Calculate the mean titre and determine the number of moles of sodium thiosulfate that reacted.

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(2 marks)

(c) Determine the amount of chlorine, in mol, present in the sample of chlorine water.

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(1 mark)

(d) Calculate the concentration of the chlorine water in $moldm^{-3}$ and in gdm^{-3}.

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(2 marks)

Hard Questions

1 (a) Citric acid, $C_6H_8O_7$, is present in lemon juice and is classed as a weak acid. 10.00 cm^3 of citric acid is reacted with sodium hydroxide, NaOH (aq) , with a concentration of 12.0 g dm^{-3} to form sodium citrate, $Na_3C_6H_5O_7$, and water. 32.10 cm^3 of sodium hydroxide was required to react with the lemon juice.

State the balanced equation for this reaction.

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(1 mark)

(b) Calculate the mass, in grams, of sodium hydroxide that reacted with the lemon juice.

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(1 mark)

(c) Determine the concentration, in mol dm^{-3}, of citric acid in the sample of lemon juice.

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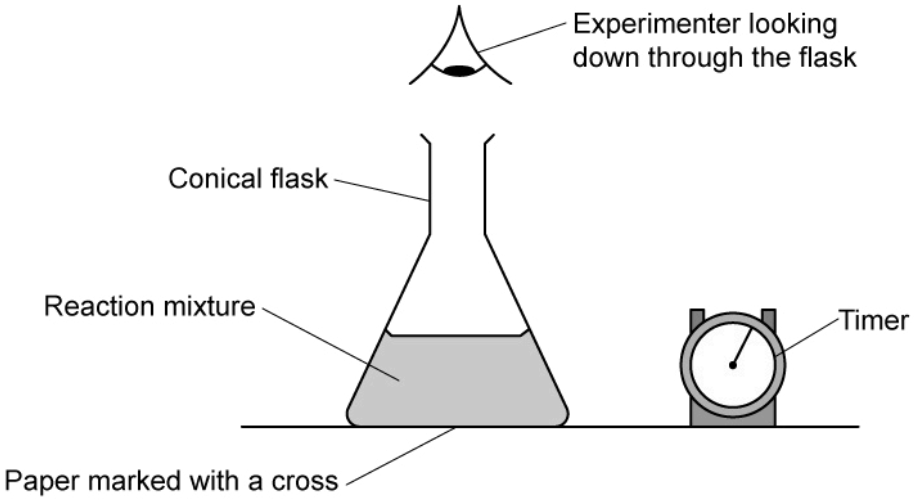
(3 marks)

2 (a) A group of students investigated the rate of reaction between sodium thiosulfate and hydrochloric acid by measuring the amount of time taken for a cross marked on a piece of paper to become obscured by a yellow precipitate.

$$Na_2S_2O_3\ (aq) + 2HCl\ (aq) \rightarrow 2NaCl\ (aq) + SO_2\ (g) + H_2O\ (l) + S\ (s)$$



Initially they measured out 15.00 cm^3 of 0.900 mol dm^{-3} hydrochloric acid and then added 40.00 cm^3 of 0.0150 mol dm^{-3} aqueous sodium thiosulfate.

The mark on the paper was obscured 38 seconds after the solutions were mixed.

Their teacher made up 3.00 dm^3 of sodium thiosulfate solution using sodium thiosulfate pentahydrate crystals, $Na_2S_2O_3 \cdot 5H_2O$.

Calculate the required mass, in grams, of these crystals. Give your answer to 2 decimal places.

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(3 marks)

Using section 2 of the Data booklet, calculate the volume of gas produced, in dm^3, in this reaction if it were collected at a temperature of 300 K and 1.00×10^5 Pa.

(b) **(4 marks)**

(c) A different group of students decided to measure the rate of reaction by collecting the volume of sulfur dioxide produced over a period of time.

The students attempted to collect the gas in a measuring cylinder over water, but were unsuccessful. Suggest why they were unsuccessful.

(1 mark)

(d) Determine the pH of the acid used and suggest how pH could be used to measure the rate of reaction.

(2 marks)

(e) Determine the reagent in excess in this reaction and state the amount, in moles, that will be in excess.

(3 marks)

3 (a) Phosphine, PH_3, is a gas formed by heating phosphorous acid, H_3PO_3, in the absence of air, as shown in the equation below.

$$4H_3PO_3\,(s) \rightarrow PH_3\,(g) + 3H_3PO_4\,(s)$$

3.45×10^{-2} mol of H_3PO_3 is completely decomposed by this reaction.

State the expected molecular shape and expected bond angle in PH_3 (g).

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(1 mark)

(b) Calculate the volume of phosphine gas formed, in cm^3, at 100 kPa pressure and 210 °C.

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(5 marks)

(c) 1.85 g of white phosphorus was used to make phosphine according to the equation.

$$P_4\,(s) + 3OH^-\,(aq) + 3H_2O\,(l) \rightarrow PH_3\,(g) + 3H_2PO_2^-\,(aq)$$

This phosphorus was reacted with 75.00 cm^3 of 4.50 mol dm^{-3} sodium hydroxide solution. Deduce, showing your working, which was the limiting reagent.

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(3 marks)

(d) Using section 2 of the Data booklet determine the volume of phosphine, measured in cm^3 at standard temperature and pressure, that was produced. Give your answer to 3 significant figures.

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(1 mark)

4 (a) A student carried out an experiment involving a solution of potassium dichromate(VI), $K_2Cr_2O_7$, with iron(II) sulfate, to find the mass of $FeSO_4.7H_2O$ in an impure sample, **A**.

The student recorded the mass of **A**, dissolved the sample in water and then made the solution up to 500 cm^3. After an excess was added, the student found that 25.00 cm^3 of this solution reacted with 22.10 cm^3 of a 0.020 mol dm^{-3} solution of $K_2Cr_2O_7$.

Deduce the full equation for the reaction between acidic $Cr_2O_7^{2-}$ (aq) and Fe^{2+} (aq) to form Cr^{3+} (aq) and Fe^{3+} (aq).

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(2 marks)

(b) Use section 6 of the Data booklet to determine the mass, in grams, of $FeSO_4.7H_2O$ in sample, **A.** Give your answer to three significant figures.

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(4 marks)

(c) A student performs a titration to determine the molar mass and structure of a dicarboxylic acid, **X**, which only contains carbon, hydrogen and oxygen.

The student prepares a 250.0 cm^3 solution from 1.513 g of X.

The solution of X is added to the burette and titrated with 25.00 cm^3 aliquot of 0.112 mol dm^{-3} NaOH (aq).

The student recorded their results in the table below:

	Titration 1	Titration 2	Titration 3
Final burette reading / cm^3	28.60	27.95	29.45
Initial burette reading / cm^3	1.10	0.70	2.10
Volume added / cm^3	27.50	27.25	27.35

i) Determine the mean volume, in dm^3, of the titre.

[1]

ii) Determine the amount, in moles, of **X** in the original sample.

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(4 marks)

(d) Using section 6 in the Data booklet, suggest a structure for **X.**

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(2 marks)

5 (a) An empty 1.5 dm^3 Tupperware container has been kept in the fridge without a lid at 5 °C. The container is removed from the fridge and allowed to reach a temperature of 21 °C. Using your knowledge of Charles's Law, determine the volume of gas, in cm^3, that escaped from the container.

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(4 marks)

(b) A balloon contains 2500 mL of helium gas at a temperature of 75 °C. Determine the new volume in mL of the gas when the temperature changes to 55 °C assuming the pressure is constant. Give your answer to three significant figures.

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(2 marks)

(c) A 10.0 L container of helium gas with a pressure of 33 000 Pa at 0 °C is heated until the new pressure is 200 000 Pa. Determine the new temperature of the gas assuming the volume remains constant.

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(2 marks)