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VCE Chemistry ½
Stoichiometry [2.3]
Homework Solutions

Admin Info & Homework Outline:

Student Name	
Questions You Need Help For	
Compulsory Questions	Pg 2 – Pg 13
Supplementary Questions	Pg 14 – Pg 27

Section A: Compulsory Questions (54 Marks)

Sub-Section [2.3.1]: Write Balanced Chemical Equations, Including Combustion

Question 1 (1 mark)

Balance the equation where H_2 gas reacts with oxygen gas to form water.

$2H_2 + O_2 \rightarrow 2H_2O$

Question 2 (4 marks)

Balance the following equations:

a. $Fe + O_2 \rightarrow Fe_2O_3$. (1 mark)

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

b. $CaCO_3 \rightarrow CaO + O_2$. (1 mark)

Balanced.

c. $AgNO_3 + Na_2SO_4 \rightarrow Ag_2SO_4 + NaNO_3$. (1 mark)

$2AgNO_3 + Na_2SO_4 \rightarrow Ag_2SO_4 + 2NaNO_3$

d. $Pb(NO_3)_2 + KI \rightarrow PbI_2 + KNO_3$. (1 mark)

$Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$

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Question 3 (4 marks)

Balance the following combustion equations:

a. Propane's complete combustion. (2 marks)

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

b. Octane's complete combustion. (2 marks)

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$

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Sub-Section [2.3.2]: Apply Stoichiometry to Find the Amount of Another Substance Used/Produced

Question 4 (2 marks)

Given the equation:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

If 4.00 moles of hydrogen gas react, how many moles of ammonia would be produced?

$4 \times \frac{2}{3} = 2.67$ moles of ammonia

Question 5 (4 marks)

Given the following equation:

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

a. If 15.0 g of Zn reacts with excess hydrochloric acid, how many grams of hydrogen gas would be produced? (2 marks)

$\frac{15}{65.4} = 0.2294$ moles

$0.2294 \times 2 = 0.459\ g$

b. If 2.00 g of H_2 gas was produced, then how much zinc was reacted in the first place, in grams? (2 marks)

$\frac{2}{2} = 1$ mole, $1 \times 1 \times 65.4 = 65.4$ grams

Question 6 (4 marks)

Given the combustion of 10.56 g of propane, C_3H_8, calculate the total mass of gases released, assuming the reaction occurred at 120°C.

Reaction: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

$n(C_3H_8) = \frac{10.56}{36} = 0.2933$ mol

$n(CO_2) = 3(0.2933) = 0.88$ mol

$n(H_2O) = 4(0.2933) = 1.1733...$ mol (gas at 120°C)

$m(CO_2) = (0.88)(12.0 + 16.0 \times 2)$
$= 38.72$ g

$m(H_2O) = (1.173...)(2.0 + 16.0)$
$= 21.12$ g

$\Rightarrow m(gas) = 38.72 + 21.12$
$= 59.839$
≈ 59.8 g (3 sig figs)

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Sub-Section [2.3.3]: Identify the Limiting Reagent When Reactants' Amounts are Known

Question 7 (2 marks)

Consider the reaction:

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

There are 10.00 g of Na_2CO_3 and 6.00 g of HCl. Determine what the limiting and excess reagents are.

$\frac{10}{23} + 23 + 12 + 48 = 0.0943$ moles

$\frac{6.00}{36.5} = 0.164$ moles $/\ 2 = 0.0822$ moles

Hence, HCl is the limiting reagent and Na_2CO_3 is the excess reagent.

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Question 8 (4 marks)

Consider the following reaction:

$$AlCl_3 + 3LiOH \rightarrow Al(OH)_3 + 3LiCl$$

There are $2.50\ mol$ of $AlCl_3$, and $5.50\ mol$ of LiOH.

a. What are the limiting and excess reagents? (2 marks)

$AlCl_3 = 2.50\ mol$

$LiOH = \frac{5.50}{3} = 1.83\ mol$

LiOH is the limiting reagent.

b. Find the mass of LiCl and $Al(OH)_3$ formed. (2 marks)

$1.83 \times 3 = 5.49$ moles

$5.49 \times (7 + 35.5) = 233.3\ g$ of LiCl formed.

$1.83 \times (27 + (17 \times 3)) = 142.7\ g$ of $Al(OH)_3$ formed.

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Question 9 (6 marks)

Consider the following reaction:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

There are 12.00 g of Fe_2O_3 and 6.00 g of CO.

a. What are the limiting and excess reagents? (2 marks)

$12/(55.8 + 55.8 + 48) = 0.0752$ moles of Fe_2O_3
$\frac{6}{12} + 16 = 0.214 \rightarrow 0.214\ /3\ = 0.0714$ moles of CO
CO is the limiting reagent.

b. Find the mass of Fe and CO_2 formed. (2 marks)

$0.214 \times 2/3 = 0.143$ moles of Fe $\times\ 55.8 = 7.96\ g$
$0.214 \times 3/3 = 0.214$ moles of $CO_2 \times 44 = 9.416\ g$
Total $= 17.38\ g$ total

c. In another experiment, if 12.58 g of CO_2 was formed then how much Fe_2O_3 was reacted initially in grams? (2 marks)

$12.58\ /44 = 0.286$ moles of CO_2 formed
$0.286 \times 1/3 = 0.095$ moles $\times\ (55.8 \times 2 + 48) = 15.21\ g$ of Fe_2O_3

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Sub-Section [2.3.4]: Apply Limiting Reagent to Calculate the Mass of Product(s) Formed, & the Amount of Excess Reagent Leftover

Question 10 (3 marks)

Given the following reaction:

$$Al + HCl \rightarrow AlCl_3 + H_2$$

a. Balance the equation. (1 mark)

$2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

b. A sample of 4.00 moles of Al and 10.00 moles of HCl reacts. What is the amount of HCl left? (2 marks)

$4 / 2 = 2.00$ moles
$10 / 6 = 1.67$ moles
HCl is limiting, and so 0 will be leftover.

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Question 11 (4 marks)

Consider the reaction:

$$Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + CO_2 + H_2O$$

a. Which is the excess and limiting reagent, given that there are 45 grams of $Na2CO_3$ and 30 grams of HNO_3? (2 marks)

$45 / 106 = 0.4245$ moles of Na_2CO_3
$30 / 63 = 0.4762$ moles of HNO_3 / $2 = 0.2381$
So therefore, HNO_3 is limiting.

b. What is the amount of excess reagent left over in grams? (2 marks)

$0.4762 / 2 = 0.2381$ moles of Na_2CO_3 reacts
Leftover $= 0.4245 - 0.2381 = 0.1864$ moles
$0.1864 \times (23 \times 2) + 12 + 48 = 19.76\ g$

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Question 12 (6 marks)

Given the following reaction:

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

a. If there are 3.20 g of sulphuric acid, H_2SO_4, and 3.28 g of NaOH, find the limiting reagent. (3 marks)

Moles of sulphuric acid $= \frac{3.2}{98.1} = 0.0326$ moles

Moles of NaOH $= \frac{3.28}{40} = 0.082$ moles

NaOH $= 0.041$ moles and sulphuric acid 0.0326 moles

Sulphuric acid is the limiting reagent.

b. What mass of the excess reagent will be left over? (2 marks)

Amount of NaOH reacting $= 0.0326 \times 2 = 0.0652$ moles

Leftover $= 0.082 - 0.0163 = 0.0168$ moles

$0.0168 \times (23 + 17) = 0.672\ g$

c. What is the percentage of the excess reagent that was used in this reaction? (1 mark)

$$\frac{3.28g - 0.672g}{3.28g} \times 100 = 80\%$$

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Sub-Section: The 'Final Boss'

Question 13 (10 marks)

Given the following reaction:

$$P_4S_3(s) + O_2(g) \rightarrow P_4O_6(g) + SO_2(g)$$

a. Balance the above reaction. (1 mark)

$P_4S_3 + 6O_2 \rightarrow P_4O_6 + 3SO_2$

b. If 3.00 g of P_4S_3 is reacted, then how much SO_2 gas would be produced? (2 marks)

$3 / (31 \times 4 + 32.1 \times 3) = 0.0136$ moles
$0.0136 \times 3 = 0.0408$ moles
$0.0408 \times (32.1 + 32) = 2.62\ g$

c. If there is 10.37 g of P_4S_3 and 9.62 g of oxygen gas, which is the limiting and excess reagent? (3 marks)

0.0471 moles of P_4S_3
0.301 moles of O_2
$0.301/6 = 0.050$ moles for O_2 and P_4S_3 stay same.
P_4S_3 is the limiting reagent.

d. Find the mass of P_4O_6 produced. (2 marks)

$0.0471 \times (31 \times 4 + (16 \times 6)) = 10.362\ g$ of P_4O_6

e. How much of the excess reagent, in mol, is left at the end of the reaction? (2 marks)

Moles used up $= 0.0471 \times 6 = 0.2826$ moles
Leftover $= 0.301 - 0.2826 = 0.0184$ moles left over

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Section B: Supplementary Questions (81 Marks)

Sub-Section [2.3.1]: Write Balanced Chemical Equations, Including Combustion

Question 14 (1 mark)

Balance the equation where CH_4 reacts with oxygen gas to form carbon dioxide and water.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Question 15 (4 marks)

Balance the following equations:

a. $KClO_3 \rightarrow KCl + O_2$. (1 mark)

$2KClO_3 \rightarrow 2KCl + 3O_2$

b. $CH_3OH + O_2 \rightarrow H_2O + CO_2$. (1 mark)

$CH_3OH + O_2 \rightarrow 2H_2O + CO_2$

c. $Ca(OH)_2 + HCl \rightarrow CaCl_2 + H_2O$. (1 mark)

$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

d. $AgCl + Mg(NO_3)_2 \rightarrow MgCl_2 + AgNO_3$. (1 mark)

$2AgCl + Mg(NO_3)_2 \rightarrow MgCl_2 + 2AgNO_3$

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Question 16 (4 marks)

Balance the following combustion equations:

a. Ethanol's complete combustion. (2 marks)

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

b. Decane's complete combustion. (2 marks)

$2C_{10}H_{22} + 31O_2 \rightarrow 20CO_2 + 22H_2O$

Question 17 (7 marks)

Consider the combustion equation of butanol.

a. Write the balanced equation, assuming that CO_2 and H_2O is produced. (2 marks)

$C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$

b. Now, consider when CO and H_2O is produced. (1 mark)

$C_4H_9OH + 5O_2 \rightarrow 4CO + 5H_2O$

c. Why is it suggested that we balance carbon last in a chemical equation generally? (2 marks)

We balance carbon last because other elements can exist in isolation whereas carbon is more likely to exist with something else and so it is harder to balance since it affects multiple species, so we leave it until the end to make it easier.

d. A student argues that we can have more matter at the end of a reaction as we are inputting energy into the reaction system as a combustion reaction usually results in our fuel disappearing over time. Evaluate this statement. (2 marks)

This is not true due to the law of conservation of mass stating that the matter that is at the start of the reaction should be present at the end of the reaction, and that matter cannot be created or destroyed, just transformed. In this case the fuel would have just transformed into energy and gas that is released into the environment and so that's why we see it as changing, but if we captured everything it would be the same amount of matter.

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Sub-Section [2.3.2]: Apply Stoichiometry to Find the Amount of Another Substance Used/Produced

Question 18 (2 marks)

Given the equation:

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

If 5.50 moles of $KClO_3$ reacts, then how much oxygen gas would be produced, in moles?

$5.50 \times 3/2 = 8.25$ moles of oxygen gas

Question 19 (4 marks)

Given the following equation:

$$2Al_2O_3 \rightarrow 4Al + 3O_2$$

a. If 7.00 g of Al_2O_3 decomposes, how many grams of O_2 gas would be produced? (2 marks)

$7 / (27 \times 2 + 16 \times 3) = 0.0686$ moles
$0.0686 \times 3/2 = 0.1029$ moles of oxygen gas $\times 32 = 3.29\ g$ of O_2 gas

b. If 3.00 g of oxygen gas was produced, how much Al_2O_3 would've been needed, in grams? (2 marks)

$3 / 32 = 0.09375 \times 2/3 = 0.0625$ moles of Al_2O_3
$0.0625 \times (27 \times 2) + (16 \times 3) = 6.375\ g$

Question 20 (4 marks)

Given the combustion of 8.49 g of propanol, C_3H_7OH, calculate the total mass of gases released, assuming the reaction occurred at 120°C.

Reaction: $2C_3H_7OH + 9O_2 \rightarrow 6CO_2 + 8H_2O$
$8.49 / 60 = 0.1415$ moles
$0.1415 \times 6/2 = 0.4245 \times 44 = 18.68\ g$ of CO_2
$0.1415 \times 8/2 = 0.566$ moles of steam $\times 18 = 10.19\ g$ of Steam
Total $= 28.87\ g$ of gas

Question 21 (9 marks)

Consider the following chemical equation:

$$H_3PO_4 + KOH \rightarrow K_3PO_4 + H_2O$$

a. Balance the above equation as it is currently unbalanced. (1 mark)

$H_3PO_4 + 3KOH \rightarrow K_3PO_4 + 3H_2O$

b. If 665.42 g of phosphoric acid (H_3PO_4) reacted, how many moles of water were produced? (2 marks)

Molar mass $= 98$
Moles $= 6.79$ moles
$6.79 \times 3 = 20.37$ moles of H_2O

c. Consider if 8.15 mol of K_3PO_4 was produced.

i. How many moles of phosphoric acid were used up? (2 marks)

$8.15 \times 1 = 8.15$ moles

ii. How much water was also produced? (2 marks)

$8.15 \times 3 = 24.45$ moles

iii. What is the mass of KOH required to get this amount of K_3PO_4? (2 marks)

$8.15 \times 3 = 24.45$ moles of KOH, $24.45 \times (39.1 + 17) = 1371.65\ g$

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Sub-Section [2.3.3]: Identify the Limiting Reagent When Reactants' Amounts are Known

Question 22 (2 marks)

Consider the reaction:

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

There are 13.00 g of $Ca(OH)_2$ and 5.00 g of HCl, determine what the limiting and excess reagents are.

0.175 moles of $Ca(OH)_2$
0.137 moles of HCl / 2 = 0.0685 moles
HCl is the limiting reagent.

Question 23 (4 marks)

9.55 g of Na_3PO_4 and 7.31 g of $CaCl_2$ are mixed and allowed to react according to this equation:

$$2Na_3PO_4 + 3CaCl_2 \rightarrow Ca_3(PO_4)_2 + 6NaCl$$

a. Which reactant is the limiting reagent? Which reactant is in excess? (2 marks)

Moles of $Na_3PO_4 = 9.55/164 = 0.0582$ moles
Moles of $CaCl_2 = 7.31 / 111.1 = 0.0658$ moles
$Na_3PO_4 = 0.0582 / 2 = 0.0291$ moles
$CaCl_2 = 0.0658/3 = 0.0219$ moles
$CaCl_2$ is the limiting reagent and Na_3PO_4 excess reagent.

b. What is the mass of $Ca_3(PO_4)_2$ that is formed? (2 marks)

$0.0658 \times 1/3 = 0.02193$ moles
$0.02193 \times (40.1 \times 3) + (31 + 64) \times 2 = 6.90\ g$

Question 24 (6 marks)

Consider the following reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

There are $14.00\ g$ of N_2 and $4.00\ g$ of H_2.

a. What are the limiting and excess reagents? (2 marks)

$14/\ 28 = 0.500$ moles of N_2
$4/2 - 2.00$ moles of $H_2 \rightarrow 2/3 = 0.667$ moles of H_2 in 1: 1 ratio
Therefore, N_2 is the limiting reagent.

b. Find the mass of NH_3 formed. (2 marks)

$0.5 \times 2 = 1.00\ mol\ NH_3$
$1 \times 17 = 17\ g$ of NH_3

c. In another experiment, if $25.5\ g$ of NH_3 was formed, how much H_2 was used initially in grams? (2 marks)

$25.5\ /\ 17 = 1.50$ moles of NH_3
$1.50 \times 3/2 = 2.25$ moles of $H_2 \times 2 = 4.50\ g$ of H_2

Question 25 (9 marks)

Consider the combustion reaction of pentane at 200°C.

a. Write the fully balanced reaction. (1 mark)

$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

b. Consider in an experiment we had 44.00 g of pentane and 160.00 g of oxygen gas.

i. What are the limiting and excess reagents? (2 marks)

$44 / 72 = 0.61$ moles
$160 / 32 = 5$ moles $/ 8 = 0.625$ moles

Pentane is the limiting reagent and oxygen gas is the excess.

ii. What is the mass of gases formed? (2 marks)

$0.61 \times 5 = 3.05$ moles of $CO_2 \times 44 = 134.2\ g$
$0.61 \times 6 = 3.66$ moles of water vapour $\times 18 = 65.88\ g$
Total $= 200.08\ g$ of gas

iii. Is this the same as the total mass of gases left over at the end of the reaction? (2 marks)

No, since there will be an amount of leftover gas at the end of the reaction from the excess reagents so it will be a bit more.

c. In another experiment, if 88.00 g of CO_2 was formed, how much O_2 was used initially in grams? (2 marks)

$88\ /44 = 2$ moles
$2 \times 8/5 = 3.20$ moles $\times\ 32 = 102.4\ g$ of oxygen gas

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Sub-Section [2.3.4]: Apply Limiting Reagent to Calculate the Mass of Product(s) Formed, & the Amount of Excess Reagent Leftover

Question 26 (3 marks)

Given the following reaction:

$$CaCl_2 + NaOH \rightarrow Ca(OH)_2 + NaCl$$

a. Balance the equation. (1 mark)

$CaCl_2 + 2NaOH \rightarrow Ca(OH)_2 + 2NaCl$

b. A sample of 5.00 moles of $CaCl_2$ and 5.00 moles of NaOH reacts. What is the amount of $CaCl_2$ that would be left over? (2 marks)

$5.00 - 2.50 = 2.50$ moles left over.

Question 27 (6 marks)

An experiment is conducted according to the following equation:

$$MnS + 2HCl \rightarrow H_2S + MnCl_2$$

If a sample contained $50.00\ g$ of MnS and $26.00\ g$ of HCl, determine the excess and limiting reagent. (2 marks

a. Which is the excess and limiting reagent? (2 marks)

$50 / 87 = 0.575$
$26 / 36.5 = 0.712 / 2 = 0.356$
HCl is limiting

b. What is the amount left of the reactants? (2 marks)

Amount of MnS that reacts $= 0.712 \times \frac{1}{2} = 0.356$
$0.575 - 0.356 = 0.219$ moles of MnS left over

Question 28 (7 marks)

Given the following reaction:

$$3Na_2CO_3(s) + 2HCl(aq) \rightarrow 6NaCl(aq) + 3CO_2(g) + H_2O(l)$$

a. Given that there was 9.40 g of sodium carbonate and 8.90 g of hydrogen chloride, find the limiting and excess reagents. (3 marks)

$9.40 / 23 + 23 + 12 + 48 = 0.0886$
$8.90 / 1 + 35.5 = 0.243$ moles of HCl
$0.0886 / 3 = 0.02867$ moles
$0.243 / 2 = 0.122$ moles

Therefore, the sodium carbonate is limiting, and hydrogen chloride is excess.

b. Find the mass of NaCl and CO_2 that will be produced. (2 marks)

$0.0886 \times 2 = 0.1732$ moles of NaCl $\rightarrow 0.1732 \times (23 + 35.5) = 10.13\ g$
$0.0886 \times 3/3 = 0.0886$ moles of carbon dioxide $\rightarrow 0.0886 \times (12 + 32) = 3.81\ g$ of CO_2

c. What is the mass of the excess reagent left over? (2 marks)

Moles reacted = $0.0886 \times 2/3 = 0.05773$ moles reacted
Left over = $0.243 - 0.05773 = 0.1853$ moles left
$0.1853 \times 36.5 = 6.76\ g$ of HCl left over.

Question 29 (9 marks)

Given the following reaction:

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

a. Given that there was $5.03\ g$ of NH_3 and $3.45\ g$ of O_2, find the limiting and excess reagents. (2 marks)

$5.03 / 17 = 0.296$ moles of NH_3
$3.45 / 32 = 0.107$ moles of O_2
$0.296 / 4 = 0.074$ moles
$0.107 / 5 = 0.0214$ moles
So, oxygen is the limiting reagent.

b. After the reaction is completed, some of the excess reagent remains.

i. Find the amount of excess reagent that is left over. (2 marks)

Moles reacted = $0.107 \times 4/5 = 0.0856$ moles reacted
Left over = $0.296 - 0.0856 = 0.210$ moles left

ii. Find the mass of the excess reagent that is left over. (1 mark)

$0.210 \times 17 = 3.58\ g$ left over

iii. Find the mass of gases produced. (2 marks)

$0.107 \times 4/5 = 0.0856$ moles
$0.0856 \times 30 = 2.568\ g$ of NO
$0.107 \times 6/5 = 0.1284$ moles $\times\ 18 = 2.311\ g$ of H_2O
Total $= 4.879\ g$ of gas

c. What is the amount, in grams, of the current limiting reagent we need to add to turn the reaction into one where the reactants fully react? (2 marks)

For full reaction: effective moles of NH3 and O2 need to be the same

Δ eff. moles $= n_{eff.}(NH_3) - n_{eff.}(O_2)$
$= 0.074 - 0.0214$
$= 0.0526$
$\therefore n_{eff}(O_2)$ needs to be increased by 0.0526
$\therefore n(O_2 \text{ increase}) = 0.0526 \times 5$ (coeff. of O_2 in eq.)
$= 0.263$ mol
$m(O_2 \text{ needed}) = 0.263 \times 32.0$ g/mol
$= 8.42$ g needs to be added

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