

Chem 10 Chapter 8

Quantities in Chemical Reactions

Practice and End of Chapter Questions

Worked solutions at the end

Use your course periodic table and a calculator as needed. Show the setup, include units, and round at the end. Question numbers match the numbers in the solutions. Use heading navigation to move between sections.

Practice Questions

Question 1

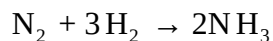
How many waffles can be made from 1 dozen eggs, assuming you have enough of all other ingredients?

Recipe: 2 cups flour + 3 eggs + 1 tablespoon oil → 4 waffles.

- A) 16
- B) 48
- C) 4
- D) 12
- E) not enough information

Question 2

Diatomic nitrogen reacts with diatomic hydrogen to form ammonia.

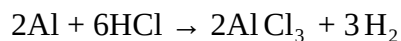


If 6 mol of H_2 react completely with more than enough N_2 , how many moles of ammonia form?

- A) 4 mol
- B) 2 mol
- C) 6 mol
- D) 3 mol
- E) not enough information

Question 3

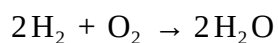
How many moles of aluminum are needed to make 9 mol of hydrogen gas?



- A) 3 mol
- B) 6 mol
- C) 2 mol
- D) 4 mol
- E) none of the above

Question 4

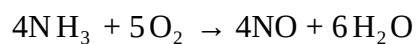
How many grams of water are made when 4.0 g of hydrogen gas react completely with sufficient oxygen?



- A) 4.5 g
- B) 18 g
- C) 72 g
- D) 36 g
- E) not enough information

Question 5

For the reaction below, how many moles of NO form when 4.50 mol H₂O form?



- A) 6.75 mol
- B) 1.50 mol
- C) 4.50 mol
- D) 3.00 mol
- E) none of the above

Question 6

You have 5 cups of flour, 9 eggs, and 3 tablespoons of oil.

Recipe: 2 cups flour + 3 eggs + 1 tablespoon oil $\rightarrow$ 4 waffles.

Which ingredient is the limiting reactant?

- A) waffles
- B) eggs
- C) flour
- D) oil
- E) not enough information

Question 7

You have 5 cups of flour, 9 eggs, and 3 tablespoons of oil.

Recipe: 2 cups flour + 3 eggs + 1 tablespoon oil $\rightarrow$ 4 waffles.

What is the theoretical yield of waffles?

- A) 12
- B) 10
- C) 4
- D) 6
- E) not enough information

Question 8

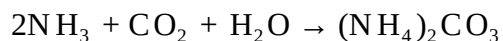
Determine the theoretical yield of C when 3 mol A and 10 mol B react.



- A) 3 mol
- B) 8 mol
- C) 6 mol
- D) 4 mol
- E) none of the above

Question 9

Ammonium carbonate can be prepared according to this equation:



Which choice of reactant quantities produces the greatest amount of ammonium carbonate?

- A) 2 mol NH_3 , 8 mol CO_2 , and 8 mol H_2O
- B) 2 mol NH_3 , 1 mol CO_2 , and 1 mol H_2O
- C) 4 mol NH_3 , 2 mol CO_2 , and 2 mol H_2O
- D) 4 mol NH_3 , 1 mol CO_2 , and 2 mol H_2O
- E) none of the above

Question 10

The theoretical yield is 42.0 g of product and the percent yield is 75%. How many grams were actually produced?

- A) 5400 g
- B) 1.8 g
- C) 32 g
- D) 56 g
- E) none of the above

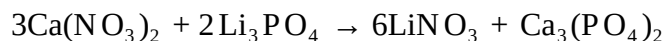
Question 11

What is the theoretical yield if 25.0 g of product were actually produced in a reaction with an 88% yield?

- A) 22.0 g
- B) 352 g
- C) 28.4 g
- D) 3.52 g
- E) none of the above

Question 12

You have 3.4 mol $\text{Ca}(\text{NO}_3)_2$ and 2.4 mol Li_3PO_4 .

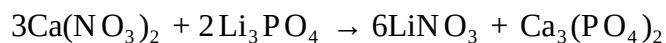


Which is the limiting reactant?

- A) $\text{Ca}(\text{NO}_3)_2$
- B) LiNO_3
- C) $\text{Ca}_3(\text{PO}_4)_2$
- D) Li_3PO_4
- E) not enough information

Question 13

You have 3.4 mol $\text{Ca}(\text{NO}_3)_2$ and 2.4 mol Li_3PO_4 .



Which is the excess reactant?

- A) LiNO_3
- B) Li_3PO_4
- C) $\text{Ca}(\text{NO}_3)_2$
- D) $\text{Ca}_3(\text{PO}_4)_2$
- E) not enough information

Question 14

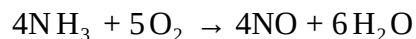
How many grams of NO_2 are theoretically produced from 1.20 mol S and 9.90 mol HNO_3 ?



- A) 455 g
- B) 331 g
- C) 7.20 g
- D) 786 g
- E) not enough information

Question 15

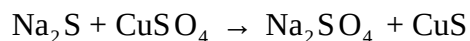
Oxidation of 8.5 g NH_3 with sufficient oxygen produces 4.5 g NO . Calculate the percent yield.



- A) 70%
- B) 15%
- C) 60%
- D) 30%
- E) none of the above

Question 16

How many grams of the excess reactant remain when 15.5 g Na_2S and 12.1 g CuSO_4 react to completion?



- A) 5.92 g
- B) 15.45 g
- C) 9.58 g
- D) 0.05 g
- E) not enough information

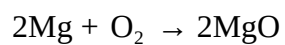
Question 17

The reaction of 1 mol nitrogen gas with 3 mol hydrogen gas releases 92 kJ of heat to the surroundings. Which statement is true?

- A) Complete reaction of 2 mol nitrogen gas releases 184 kJ in this reaction.
- B) The reaction is exothermic.
- C) The reaction has a negative enthalpy change.
- D) All of the above are true.
- E) None of the above are true.

Question 18

Calculate the heat, in kJ, associated with complete reaction of 4 mol Mg.



$$\Delta H = -1203 \text{ kJ}$$

- A) -1203 kJ
- B) -2406 kJ
- C) -4812 kJ
- D) -601.5 kJ
- E) none of the above

End of Chapter Questions

Question 19

How many moles of C form when each amount reacts completely? Assume the other reactant is in excess.



- (a) 2 mol A
- (b) 2 mol B
- (c) 3 mol A
- (d) 3 mol B

Question 20

For the reaction below, calculate the moles of NO_2 produced by complete reaction of each amount of N_2O_5 .

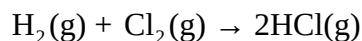


- (a) 1.3 mol N_2O_5
- (b) 5.8 mol N_2O_5
- (c) 4.45×10^3 mol N_2O_5
- (d) 1.006×10^{-3} mol N_2O_5

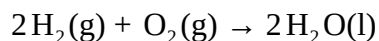
Question 21

For each reaction, calculate the moles of product obtained from 1.75 mol of the stated reactant. The other reactant is in excess.

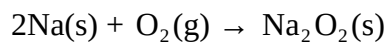
- (a) Given 1.75 mol H_2 :



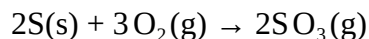
- (b) Given 1.75 mol O_2 :



- (c) Given 1.75 mol Na:

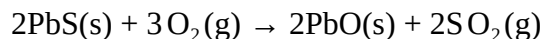


- (d) Given 1.75 mol O_2 :



Question 22

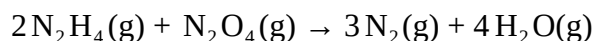
Calculate the moles of each product formed from each stated amount. Assume the other reactant is in excess.



- (a) 2.4 mol PbS
- (b) 2.4 mol O₂
- (c) 5.3 mol PbS
- (d) 5.3 mol O₂

Question 23

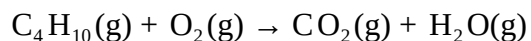
Complete the table of amounts consumed or formed in the reaction. All amounts are in moles; each row is a separate case. A dash marks an entry to fill in.



Row	N ₂ H ₄ (mol)	N ₂ O ₄ (mol)	N ₂ (mol)	H ₂ O (mol)
(a)	—	2	—	—
(b)	6	—	—	—
(c)	—	—	—	8
(d)	—	5.5	—	—
(e)	3	—	—	—
(f)	—	—	12.4	—

Question 24

Balance the equation for complete combustion of butane, then calculate the moles of O₂ needed to react with 4.9 mol C₄H₁₀.

**Question 25**

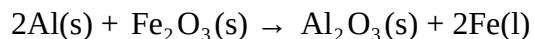
Calculate the grams of O₂ produced by complete decomposition of each amount of HgO.



- (a) 2.13 g HgO
- (b) 6.77 g HgO
- (c) 1.55 kg HgO
- (d) 3.87 mg HgO

Question 26

Calculate the grams of each product formed from each stated amount. Assume the other reactant is in excess.

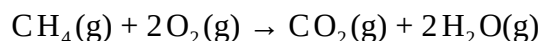


(a) 4.7 g Al

(b) 4.7 g Fe_2O_3

Question 27

Complete the table of masses consumed or formed in the reaction. Each row is a separate case. A dash marks an entry to fill in.



Row	CH_4	O_2	CO_2	H_2O
(a)	—	2.57 g	—	—
(b)	22.32 g	—	—	—
(c)	—	—	—	11.32 g
(d)	—	—	2.94 g	—
(e)	3.18 kg	—	—	—
(f)	—	—	2.35×10^3 kg	—

Question 28

Determine the limiting reactant for each initial mixture.



(a) 2 mol A and 5 mol B

(b) 1.8 mol A and 4 mol B

(c) 3 mol A and 4 mol B

(d) 22 mol A and 40 mol B

Question 29

Determine the theoretical yield of C, in moles, for each initial mixture.



(a) 1 mol A and 1 mol B

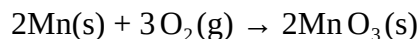
(b) 2 mol A and 2 mol B

(c) 1 mol A and 3 mol B

(d) 32 mol A and 68 mol B

Question 30

For the equation as written, calculate the theoretical yield of product, in moles, for each initial mixture.



- (a) 2 mol Mn and 2 mol O₂
- (b) 4.8 mol Mn and 8.5 mol O₂
- (c) 0.114 mol Mn and 0.161 mol O₂
- (d) 27.5 mol Mn and 43.8 mol O₂

Question 31

A vessel initially contains 9 mol A and 8 mol B. How many moles of A, B, and C remain after the reactants have reacted as much as possible? Assume 100% yield.

**Question 32**

The diagrams show initial relative amounts of HCl and O₂. Treat each particle symbol as the same amount of molecules, rather than as a literal single molecule. How many particle units of Cl₂ are formed in each case at 100% yield?

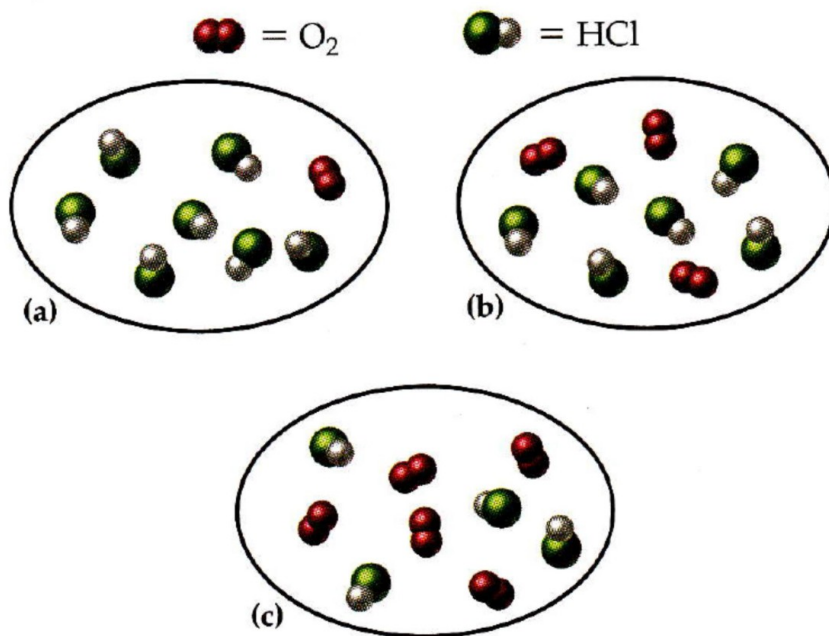
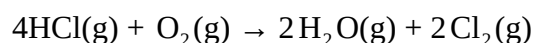
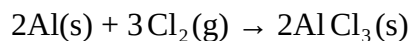


Figure description: Three initial-mixture diagrams. Oxygen is shown as a pair of like red spheres; hydrogen chloride is a green sphere joined to a smaller pale sphere. Diagram (a) contains 7 HCl symbols and 1 O₂ symbol. Diagram (b) contains 6 HCl symbols and 3 O₂ symbols. Diagram (c) contains 4 HCl symbols and 5 O₂ symbols.

Question 33

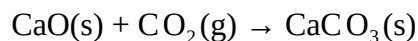
Calculate the theoretical yield of AlCl_3 , in grams, for each initial mixture.



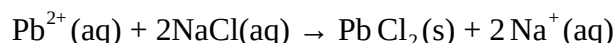
- (a) 1.0 g Al and 1.0 g Cl_2
- (b) 5.5 g Al and 19.8 g Cl_2
- (c) 0.439 g Al and 2.29 g Cl_2

Question 34

A chemist allows 14.4 g CaO and 13.8 g CO_2 to react, then collects 19.4 g CaCO_3 . Determine the limiting reactant, theoretical yield, and percent yield.

**Question 35**

A solution containing 195.7 g Pb^{2+} is treated with 135.8 g NaCl . The PbCl_2 precipitate is filtered, dried, and found to have a mass of 252.4 g. Determine the limiting reactant, theoretical yield of PbCl_2 , and percent yield.

**Question 36**

Classify each process as exothermic or endothermic and state the sign of its enthalpy change.

- (a) Butane gas burning in a lighter
- (b) The reaction in a chemical cold pack used to ice an athletic injury
- (c) Wax burning in a candle

Question 37

Determine the heat emitted when each stated amount reacts completely. Assume the other reactant is in excess.

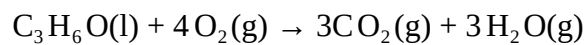


$$\Delta H = -55 \text{ kJ}$$

- (a) 1 mol A
- (b) 2 mol A
- (c) 1 mol B
- (d) 2 mol B

Question 38

Acetone, $\text{C}_3\text{H}_6\text{O}$, is the main ingredient in many nail-polish removers. How much heat is released by complete combustion of 155 g acetone?



$$\Delta H = -1790 \text{ kJ}$$

Solutions

Find the solution with the same question number.

Question 1 Solution

A. The recipe gives the ratio of waffles to eggs. A dozen is 12 eggs.

$$12 \text{ eggs} \times \frac{4 \text{ waffles}}{3 \text{ eggs}} = 16 \text{ waffles}$$

Question 2 Solution

A. Use the coefficients of H_2 and NH_3 as a mole ratio.

$$6 \text{ mol H}_2 \times \frac{2 \text{ mol NH}_3}{3 \text{ mol H}_2} = 4 \text{ mol NH}_3$$

Question 3 Solution

B. The equation requires 2 mol Al for every 3 mol H_2 formed.

$$9 \text{ mol H}_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol H}_2} = 6 \text{ mol Al}$$

Question 4 Solution

D. The coefficients relate moles, not grams. Go from grams of H_2 to moles, use the mole ratio, and then go back to grams of H_2O .

$$4.0 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.016 \text{ g H}_2} \times \frac{2 \text{ mol H}_2\text{O}}{2 \text{ mol H}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 36 \text{ g H}_2\text{O}$$

Question 5 Solution

D. Both product amounts follow the same reaction ratio.

$$4.50 \text{ mol H}_2\text{O} \times \frac{4 \text{ mol NO}}{6 \text{ mol H}_2\text{O}} = 3.00 \text{ mol NO}$$

Question 6 Solution

C. Divide each available amount by the amount required for one recipe. The smallest result determines how many recipes can be made.

$$\text{Flour: } \frac{5 \text{ cups}}{2 \text{ cups per recipe}} = 2.5 \text{ recipes}$$

$$\text{Eggs: } \frac{9 \text{ eggs}}{3 \text{ eggs per recipe}} = 3 \text{ recipes}$$

$$\text{Oil: } \frac{3 \text{ tablespoons}}{1 \text{ tablespoon per recipe}} = 3 \text{ recipes}$$

Flour allows the fewest recipes, so flour is limiting.

Question 7 Solution

B. Flour is the limiting ingredient: it permits 2.5 recipes, whereas the eggs and oil each permit 3 recipes. Use the amount of flour to calculate the theoretical yield.

$$5 \text{ cups flour} \times \frac{4 \text{ waffles}}{2 \text{ cups flour}} = 10 \text{ waffles}$$

Question 8 Solution

C. Divide moles available by the respective coefficients: A gives $3/2 = 1.5$; B gives $10/5 = 2$. The smaller value belongs to A, so A is limiting.

$$3 \text{ mol A} \times \frac{4 \text{ mol C}}{2 \text{ mol A}} = 6 \text{ mol C}$$

Question 9 Solution

C. For each choice, divide each reactant amount by its coefficient. The smallest value gives the amount of product because the product coefficient is 1.

A) Minimum of $2/2$, $8/1$, and $8/1$: 1 mol product.

B) Minimum of $2/2$, $1/1$, and $1/1$: 1 mol product.

C) Minimum of $4/2$, $2/1$, and $2/1$: 2 mol product.

D) Minimum of $4/2$, $1/1$, and $2/1$: 1 mol product.

Choice C makes the greatest amount: 2 mol $(\text{NH}_4)_2\text{CO}_3$.

Question 10 Solution

C. The actual yield is the stated fraction of the theoretical yield.

$$\text{Actual yield} = 42.0 \text{ g} \times \frac{75}{100} = 31.5 \text{ g}$$

Round to two significant figures: 32 g.

Question 11 Solution

C. Start with the definition of percent yield and solve for the theoretical yield.

$$\text{Percent yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

$$\text{Theoretical yield} = \frac{25.0 \text{ g}}{0.88} = 28.409... \text{ g}$$

This matches choice C, 28.4 g. Strict rounding to the two significant figures in 88% gives 28 g.

Question 12 Solution

A. Divide each amount in moles by its coefficient.

$$\text{Ca}(\text{NO}_3)_2: \frac{3.4}{3} = 1.13\dots$$

$$\text{Li}_3\text{PO}_4: \frac{2.4}{2} = 1.2$$

The smaller value belongs to $\text{Ca}(\text{NO}_3)_2$, so it is limiting. The unrounded values determine the comparison.

Question 13 Solution

B. $\text{Ca}(\text{NO}_3)_2$ is limiting because $3.4/3$ is smaller than $2.4/2$. Calculate how much Li_3PO_4 is needed to consume all of it.

$$3.4 \text{ mol Ca}(\text{NO}_3)_2 \times \frac{2 \text{ mol Li}_3\text{PO}_4}{3 \text{ mol Ca}(\text{NO}_3)_2} = 2.27\dots \text{ mol Li}_3\text{PO}_4$$

We have 2.4 mol Li_3PO_4 , which is more than required. Li_3PO_4 is the excess reactant.

Question 14 Solution

B. Compare moles divided by coefficients: S gives $1.20/1 = 1.20$; HNO_3 gives $9.90/6 = 1.65$. S is limiting.

$$1.20 \text{ mol S} \times \frac{6 \text{ mol NO}_2}{1 \text{ mol S}} \times \frac{46.01 \text{ g NO}_2}{1 \text{ mol NO}_2} = 331 \text{ g NO}_2$$

Question 15 Solution

D. Use the starting amount of NH_3 to find the theoretical yield of NO.

$$8.5 \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.03 \text{ g NH}_3} \times \frac{4 \text{ mol NO}}{4 \text{ mol NH}_3} \times \frac{30.01 \text{ g NO}}{1 \text{ mol NO}} = 14.98\dots \text{ g NO}$$

$$\text{Percent yield} = \frac{4.5 \text{ g}}{14.98\dots \text{ g}} \times 100 = 30\%$$

The actual yield is about three tenths of the theoretical yield.

Question 16 Solution

C. First convert the reactant masses to moles. The coefficients are both 1, so the smaller mole amount is limiting.

$$n(\text{Na}_2\text{S}) = 15.5 \text{ g} \times \frac{1 \text{ mol}}{78.05 \text{ g}} = 0.1986 \text{ mol}$$

$$n(\text{CuSO}_4) = 12.1 \text{ g} \times \frac{1 \text{ mol}}{159.62 \text{ g}} = 0.07581 \text{ mol}$$

CuSO_4 is limiting. Calculate the mass of Na_2S consumed, then subtract it from the starting mass.

$$12.1 \text{ g CuSO}_4 \times \frac{1 \text{ mol CuSO}_4}{159.62 \text{ g CuSO}_4} \times \frac{1 \text{ mol Na}_2\text{S}}{1 \text{ mol CuSO}_4} \times \frac{78.05 \text{ g Na}_2\text{S}}{1 \text{ mol Na}_2\text{S}} = 5.916... \text{ g Na}_2\text{S}$$

$$\text{Mass remaining} = 15.5 \text{ g} - 5.916... \text{ g} = 9.583... \text{ g Na}_2\text{S}$$

This matches choice C, 9.58 g. Rounding the subtraction to tenths gives 9.6 g.

Question 17 Solution

D. All three statements are true. Doubling the amount reacted doubles the heat released: $2 \times 92 \text{ kJ} = 184 \text{ kJ}$. A reaction that releases heat is exothermic. Its enthalpy change is negative because the reacting system loses energy as heat.

Question 18 Solution

B. The enthalpy value belongs to the equation as written: -1203 kJ for 2 mol Mg reacting.

$$q = 4 \text{ mol Mg} \times \frac{-1203 \text{ kJ}}{2 \text{ mol Mg}} = -2406 \text{ kJ}$$

The negative sign means 2406 kJ of heat is released.

Question 19 Solution

Use 1 mol C per 1 mol A, or 1 mol C per 2 mol B. The coefficients refer to moles.

$$(a) 2 \text{ mol A} \times \frac{1 \text{ mol C}}{1 \text{ mol A}} = 2 \text{ mol C}$$

$$(b) 2 \text{ mol B} \times \frac{1 \text{ mol C}}{2 \text{ mol B}} = 1 \text{ mol C}$$

$$(c) 3 \text{ mol A} \times \frac{1 \text{ mol C}}{1 \text{ mol A}} = 3 \text{ mol C}$$

$$(d) 3 \text{ mol B} \times \frac{1 \text{ mol C}}{2 \text{ mol B}} = 1.5 \text{ mol C}$$

Question 20 Solution

Every 2 mol N_2O_5 produce 4 mol NO_2 . Multiply each amount by the same exact mole ratio.

$$(a) 1.3 \text{ mol } \text{N}_2\text{O}_5 \times \frac{4 \text{ mol } \text{NO}_2}{2 \text{ mol } \text{N}_2\text{O}_5} = 2.6 \text{ mol } \text{NO}_2$$

$$(b) 5.8 \text{ mol } \text{N}_2\text{O}_5 \times \frac{4 \text{ mol } \text{NO}_2}{2 \text{ mol } \text{N}_2\text{O}_5} = 11.6 \text{ mol } \text{NO}_2$$

With two significant figures, part (b) is 12 mol NO_2 .

$$(c) 4.45 \times 10^3 \text{ mol } \text{N}_2\text{O}_5 \times \frac{4 \text{ mol } \text{NO}_2}{2 \text{ mol } \text{N}_2\text{O}_5} = 8.90 \times 10^3 \text{ mol } \text{NO}_2$$

$$(d) 1.006 \times 10^{-3} \text{ mol } \text{N}_2\text{O}_5 \times \frac{4 \text{ mol } \text{NO}_2}{2 \text{ mol } \text{N}_2\text{O}_5} = 2.012 \times 10^{-3} \text{ mol } \text{NO}_2$$

Question 21 Solution

Use the coefficient of the product over the coefficient of the stated reactant.

$$(a) 1.75 \text{ mol } \text{H}_2 \times \frac{2 \text{ mol } \text{HCl}}{1 \text{ mol } \text{H}_2} = 3.50 \text{ mol } \text{HCl}$$

$$(b) 1.75 \text{ mol } \text{O}_2 \times \frac{2 \text{ mol } \text{H}_2\text{O}}{1 \text{ mol } \text{O}_2} = 3.50 \text{ mol } \text{H}_2\text{O}$$

$$(c) 1.75 \text{ mol } \text{Na} \times \frac{1 \text{ mol } \text{Na}_2\text{O}_2}{2 \text{ mol } \text{Na}} = 0.875 \text{ mol } \text{Na}_2\text{O}_2$$

$$(d) 1.75 \text{ mol } \text{O}_2 \times \frac{2 \text{ mol } \text{SO}_3}{3 \text{ mol } \text{O}_2} = 1.17 \text{ mol } \text{SO}_3$$

Question 22 Solution

PbO and SO₂ have equal coefficients, so they form in equal mole amounts. For each product, use a ratio of 2/2 from PbS or 2/3 from O₂.

$$(a) 2.4 \text{ mol PbS} \times \frac{2 \text{ mol PbO}}{2 \text{ mol PbS}} = 2.4 \text{ mol PbO}$$

Also 2.4 mol SO₂.

$$(b) 2.4 \text{ mol O}_2 \times \frac{2 \text{ mol PbO}}{3 \text{ mol O}_2} = 1.6 \text{ mol PbO}$$

Also 1.6 mol SO₂.

$$(c) 5.3 \text{ mol PbS} \times \frac{2 \text{ mol PbO}}{2 \text{ mol PbS}} = 5.3 \text{ mol PbO}$$

Also 5.3 mol SO₂.

$$(d) 5.3 \text{ mol O}_2 \times \frac{2 \text{ mol PbO}}{3 \text{ mol O}_2} = 3.5 \text{ mol PbO}$$

Also 3.5 mol SO₂.

Question 23 Solution

The mole amounts are in the ratio 2 : 1 : 3 : 4. Divide the given amount by its coefficient, then multiply by each desired coefficient.

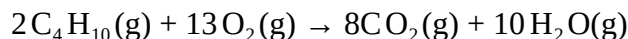
For example, in row (b), 6 mol N₂H₄ divided by 2 gives a reaction amount of 3 mol. Multiplying by 1, 3, and 4 gives 3 mol N₂O₄, 9 mol N₂, and 12 mol H₂O.

For row (f), keep the unrounded value 12.4/3 until the final step. The completed table is below.

Row	N ₂ H ₄ (mol)	N ₂ O ₄ (mol)	N ₂ (mol)	H ₂ O (mol)
(a)	4	2	6	8
(b)	6	3	9	12
(c)	4	2	6	8
(d)	11	5.5	16.5	22
(e)	3	1.5	4.5	6
(f)	8.27	4.13	12.4	16.5

Question 24 Solution

Balance C and H first, then O. One C_4H_{10} needs 4 CO_2 and 5 H_2O , giving 13 oxygen atoms on the product side. This requires $13/2 \text{ O}_2$. Multiply all coefficients by 2.



$$4.9 \text{ mol C}_4\text{H}_{10} \times \frac{13 \text{ mol O}_2}{2 \text{ mol C}_4\text{H}_{10}} = 31.85 \text{ mol O}_2$$

To two significant figures, 32 mol O_2 are required.

Question 25 Solution

Use $M(\text{HgO}) = 216.59 \text{ g/mol}$ and $M(\text{O}_2) = 32.00 \text{ g/mol}$. Convert each starting amount to grams, then use the 1-to-2 mole ratio.

$$(a) 2.13 \text{ g HgO} \times \frac{1 \text{ mol HgO}}{216.59 \text{ g HgO}} \times \frac{1 \text{ mol O}_2}{2 \text{ mol HgO}} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 0.157 \text{ g O}_2$$

$$(b) 6.77 \text{ g HgO} \times \frac{1 \text{ mol HgO}}{216.59 \text{ g HgO}} \times \frac{1 \text{ mol O}_2}{2 \text{ mol HgO}} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 0.500 \text{ g O}_2$$

$$(c) 1.55 \text{ kg HgO} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 1550 \text{ g HgO}$$

$$1550 \text{ g HgO} \times \frac{1 \text{ mol HgO}}{216.59 \text{ g HgO}} \times \frac{1 \text{ mol O}_2}{2 \text{ mol HgO}} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 115 \text{ g O}_2$$

$$(d) 3.87 \text{ mg HgO} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.00387 \text{ g HgO}$$

$$0.00387 \text{ g HgO} \times \frac{1 \text{ mol HgO}}{216.59 \text{ g HgO}} \times \frac{1 \text{ mol O}_2}{2 \text{ mol HgO}} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 2.86 \times 10^{-4} \text{ g O}_2$$

Question 26 Solution

Use these molar masses: Al, 26.98 g/mol; Fe₂O₃, 159.70 g/mol; Al₂O₃, 101.96 g/mol; Fe, 55.85 g/mol.

(a) Start with the amount of Al. Each 2 mol Al make 1 mol Al₂O₃ and 2 mol Fe.

$$4.7 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{1 \text{ mol Al}_2\text{O}_3}{2 \text{ mol Al}} \times \frac{101.96 \text{ g Al}_2\text{O}_3}{1 \text{ mol Al}_2\text{O}_3} = 8.9 \text{ g Al}_2\text{O}_3$$

$$4.7 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{2 \text{ mol Fe}}{2 \text{ mol Al}} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 9.7 \text{ g Fe}$$

(b) Start with the amount of Fe₂O₃. Each mole makes 1 mol Al₂O₃ and 2 mol Fe.

$$4.7 \text{ g Fe}_2\text{O}_3 \times \frac{1 \text{ mol Fe}_2\text{O}_3}{159.70 \text{ g Fe}_2\text{O}_3} \times \frac{1 \text{ mol Al}_2\text{O}_3}{1 \text{ mol Fe}_2\text{O}_3} \times \frac{101.96 \text{ g Al}_2\text{O}_3}{1 \text{ mol Al}_2\text{O}_3} = 3.0 \text{ g Al}_2\text{O}_3$$

$$4.7 \text{ g Fe}_2\text{O}_3 \times \frac{1 \text{ mol Fe}_2\text{O}_3}{159.70 \text{ g Fe}_2\text{O}_3} \times \frac{2 \text{ mol Fe}}{1 \text{ mol Fe}_2\text{O}_3} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 3.3 \text{ g Fe}$$

Question 27 Solution

We cannot use the coefficients directly as mass ratios. First convert the given mass to moles, use the coefficients, then convert each amount to mass.

Use molar masses of 16.04 g/mol for CH₄, 32.00 g/mol for O₂, 44.01 g/mol for CO₂, and 18.02 g/mol for H₂O.

For row (a), use the given O₂ mass. The other rows follow the same method.

$$2.57 \text{ g O}_2 \times \frac{1 \text{ mol O}_2}{32.00 \text{ g O}_2} \times \frac{1 \text{ mol CH}_4}{2 \text{ mol O}_2} \times \frac{16.04 \text{ g CH}_4}{1 \text{ mol CH}_4} = 0.644 \text{ g CH}_4$$

$$2.57 \text{ g O}_2 \times \frac{1 \text{ mol O}_2}{32.00 \text{ g O}_2} \times \frac{1 \text{ mol CO}_2}{2 \text{ mol O}_2} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 1.77 \text{ g CO}_2$$

$$2.57 \text{ g O}_2 \times \frac{1 \text{ mol O}_2}{32.00 \text{ g O}_2} \times \frac{2 \text{ mol H}_2\text{O}}{2 \text{ mol O}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 1.45 \text{ g H}_2\text{O}$$

For rows (e) and (f), the same mass ratios work when all masses in a row are in kilograms. The completed table is below.

Row	CH ₄	O ₂	CO ₂	H ₂ O
(a)	0.644 g	2.57 g	1.77 g	1.45 g
(b)	22.32 g	89.06 g	61.24 g	50.15 g
(c)	5.038 g	20.10 g	13.82 g	11.32 g
(d)	1.07 g	4.28 g	2.94 g	2.41 g
(e)	3.18 kg	12.7 kg	8.73 kg	7.15 kg
(f)	856 kg	3.42 × 10 ³ kg	2.35 × 10 ³ kg	1.92 × 10 ³ kg

Question 28 Solution

Divide the available moles of A by 2 and those of B by 4. The smaller value identifies the limiting reactant.

(a) A: $2/2 = 1$; B: $5/4 = 1.25$. A is limiting.

(b) A: $1.8/2 = 0.90$; B: $4/4 = 1$. A is limiting.

(c) A: $3/2 = 1.5$; B: $4/4 = 1$. B is limiting.

(d) A: $22/2 = 11$; B: $40/4 = 10$. B is limiting.

Question 29 Solution

Compare moles divided by coefficients, then calculate C from the limiting reactant.

(a) Compare $1/1$ with $1/2$. B is limiting.

$$1 \text{ mol B} \times \frac{3 \text{ mol C}}{2 \text{ mol B}} = 1.5 \text{ mol C}$$

(b) Compare $2/1$ with $2/2$. B is limiting.

$$2 \text{ mol B} \times \frac{3 \text{ mol C}}{2 \text{ mol B}} = 3 \text{ mol C}$$

(c) Compare $1/1$ with $3/2$. A is limiting.

$$1 \text{ mol A} \times \frac{3 \text{ mol C}}{1 \text{ mol A}} = 3 \text{ mol C}$$

(d) Compare $32/1$ with $68/2$. A is limiting.

$$32 \text{ mol A} \times \frac{3 \text{ mol C}}{1 \text{ mol A}} = 96 \text{ mol C}$$

Question 30 Solution

Use the stated equation as a stoichiometric model. Compare $n(\text{Mn})/2$ and $n(\text{O}_2)/3$, then use the limiting reactant.

(a) $2/2 = 1$; $2/3 = 0.667$. O_2 is limiting.

$$2 \text{ mol O}_2 \times \frac{2 \text{ mol MnO}_3}{3 \text{ mol O}_2} = 1.33 \dots \text{ mol MnO}_3$$

(b) $4.8/2 = 2.4$; $8.5/3 = 2.83$. Mn is limiting.

$$4.8 \text{ mol Mn} \times \frac{2 \text{ mol MnO}_3}{2 \text{ mol Mn}} = 4.8 \text{ mol MnO}_3$$

(c) $0.114/2 = 0.0570$; $0.161/3 = 0.05367$. O_2 is limiting.

$$0.161 \text{ mol O}_2 \times \frac{2 \text{ mol MnO}_3}{3 \text{ mol O}_2} = 0.107 \text{ mol MnO}_3$$

(d) $27.5/2 = 13.75$; $43.8/3 = 14.6$. Mn is limiting.

$$27.5 \text{ mol Mn} \times \frac{2 \text{ mol MnO}_3}{2 \text{ mol Mn}} = 27.5 \text{ mol MnO}_3$$

Part (a) treats the small whole-number quantities as a ratio exercise.

Question 31 Solution

Compare $9/3 = 3$ with $8/4 = 2$. B is limiting, so all 8 mol B are consumed.

$$\text{A consumed} = 8 \text{ mol B} \times \frac{3 \text{ mol A}}{4 \text{ mol B}} = 6 \text{ mol A}$$

$$\text{A remaining} = 9 \text{ mol} - 6 \text{ mol} = 3 \text{ mol A}$$

$$\text{C formed} = 8 \text{ mol B} \times \frac{2 \text{ mol C}}{4 \text{ mol B}} = 4 \text{ mol C}$$

Final amounts: 3 mol A, 0 mol B, and 4 mol C.

Question 32 Solution

The ratio is 4 particle units HCl to 1 particle unit O₂, producing 2 particle units Cl₂. Compare the starting amounts divided by their coefficients.

(a) HCl: $7/4 = 1.75$; O₂: $1/1 = 1$. O₂ is limiting.

$$1 \text{ unit O}_2 \times \frac{2 \text{ units Cl}_2}{1 \text{ unit O}_2} = 2 \text{ units Cl}_2$$

(b) HCl: $6/4 = 1.5$; O₂: $3/1 = 3$. HCl is limiting.

$$6 \text{ units HCl} \times \frac{2 \text{ units Cl}_2}{4 \text{ units HCl}} = 3 \text{ units Cl}_2$$

(c) HCl: $4/4 = 1$; O₂: $5/1 = 5$. HCl is limiting.

$$4 \text{ units HCl} \times \frac{2 \text{ units Cl}_2}{4 \text{ units HCl}} = 2 \text{ units Cl}_2$$

The answers are 2, 3, and 2 particle units of Cl₂, respectively.

Question 33 Solution

Use molar masses of 26.98 g/mol for Al, 70.90 g/mol for Cl₂, and 133.33 g/mol for AlCl₃. Convert to moles, then divide by the coefficients 2 and 3.

(a) Al: $(1.0/26.98)/2 = 0.01853$; Cl₂: $(1.0/70.90)/3 = 0.004701$. Cl₂ is limiting.

$$1.0 \text{ g Cl}_2 \times \frac{1 \text{ mol Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{2 \text{ mol AlCl}_3}{3 \text{ mol Cl}_2} \times \frac{133.33 \text{ g AlCl}_3}{1 \text{ mol AlCl}_3} = 1.3 \text{ g AlCl}_3$$

(b) Al: $(5.5/26.98)/2 = 0.1019$; Cl₂: $(19.8/70.90)/3 = 0.09309$. Cl₂ is limiting.

$$19.8 \text{ g Cl}_2 \times \frac{1 \text{ mol Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{2 \text{ mol AlCl}_3}{3 \text{ mol Cl}_2} \times \frac{133.33 \text{ g AlCl}_3}{1 \text{ mol AlCl}_3} = 24.8 \text{ g AlCl}_3$$

The limiting reactant amount, 19.8 g Cl₂, supports three significant figures in this yield.

(c) Al: $(0.439/26.98)/2 = 0.008136$; Cl₂: $(2.29/70.90)/3 = 0.01077$. Al is limiting.

$$0.439 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{2 \text{ mol AlCl}_3}{2 \text{ mol Al}} \times \frac{133.33 \text{ g AlCl}_3}{1 \text{ mol AlCl}_3} = 2.17 \text{ g AlCl}_3$$

Question 34 Solution

First find the moles of each reactant. The coefficients are both 1.

$$n(\text{CaO}) = 14.4 \text{ g} \times \frac{1 \text{ mol}}{56.08 \text{ g}} = 0.2568 \text{ mol}$$

$$n(\text{CO}_2) = 13.8 \text{ g} \times \frac{1 \text{ mol}}{44.01 \text{ g}} = 0.3136 \text{ mol}$$

CaO is limiting. Use its amount to calculate the theoretical yield.

$$14.4 \text{ g CaO} \times \frac{1 \text{ mol CaO}}{56.08 \text{ g CaO}} \times \frac{1 \text{ mol CaCO}_3}{1 \text{ mol CaO}} \times \frac{100.09 \text{ g CaCO}_3}{1 \text{ mol CaCO}_3} = 25.7 \text{ g CaCO}_3$$

$$\text{Percent yield} = \frac{19.4 \text{ g}}{25.7007... \text{ g}} \times 100 = 75.5\%$$

Question 35 Solution

Convert the two given masses to moles. The mass of an ion is taken as the atomic molar mass at this precision.

$$n(\text{Pb}^{2+}) = 195.7 \text{ g} \times \frac{1 \text{ mol}}{207.2 \text{ g}} = 0.94450 \text{ mol}$$

$$n(\text{NaCl}) = 135.8 \text{ g} \times \frac{1 \text{ mol}}{58.44 \text{ g}} = 2.32375 \text{ mol}$$

Divide by coefficients: Pb^{2+} gives $0.94450/1 = 0.94450$; NaCl gives $2.32375/2 = 1.16188$. Pb^{2+} is limiting.

$$195.7 \text{ g Pb}^{2+} \times \frac{1 \text{ mol Pb}^{2+}}{207.2 \text{ g Pb}^{2+}} \times \frac{1 \text{ mol PbCl}_2}{1 \text{ mol Pb}^{2+}} \times \frac{278.10 \text{ g PbCl}_2}{1 \text{ mol PbCl}_2} = 262.7 \text{ g PbCl}_2$$

$$\text{Percent yield} = \frac{252.4 \text{ g}}{262.6649... \text{ g}} \times 100 = 96.09\%$$

Question 36 Solution

A negative enthalpy change means the reacting system releases heat; a positive change means it absorbs heat.

(a) Exothermic; ΔH is negative. Burning butane releases heat to the surroundings.

(b) Endothermic; ΔH is positive. The cold-pack process absorbs heat from its surroundings, including the injured area.

(c) Exothermic; ΔH is negative. Burning wax releases heat. This refers to combustion, not the separate melting of wax.

Question 37 Solution

The equation releases 55 kJ for each 1 mol A or 2 mol B consumed. "Heat emitted" is reported as a positive amount; the reaction heat q has the opposite sign.

$$(a) 1 \text{ mol A} \times \frac{55 \text{ kJ emitted}}{1 \text{ mol A}} = 55 \text{ kJ emitted}$$

$$(b) 2 \text{ mol A} \times \frac{55 \text{ kJ emitted}}{1 \text{ mol A}} = 110 \text{ kJ emitted}$$

$$(c) 1 \text{ mol B} \times \frac{55 \text{ kJ emitted}}{2 \text{ mol B}} = 27.5 \text{ kJ emitted}$$

$$(d) 2 \text{ mol B} \times \frac{55 \text{ kJ emitted}}{2 \text{ mol B}} = 55 \text{ kJ emitted}$$

The corresponding reaction heats are -55 , -110 , -27.5 , and -55 kJ. To two significant figures, part (c) is 28 kJ emitted and part (b) is 1.1×10^2 kJ emitted.

Question 38 Solution

The equation releases 1790 kJ per mole of acetone. Convert the given mass to moles, then use that energy-to-mole ratio.

$$155 \text{ g C}_3\text{H}_6\text{O} \times \frac{1 \text{ mol C}_3\text{H}_6\text{O}}{58.08 \text{ g C}_3\text{H}_6\text{O}} \times \frac{1790 \text{ kJ released}}{1 \text{ mol C}_3\text{H}_6\text{O}} = 4.78 \times 10^3 \text{ kJ released}$$

For the reacting system, $q = -4.78 \times 10^3$ kJ.