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Stoichiometry: From Moles to Reactions

Study Guide — Chemical Reactions & Stoichiometry

A comprehensive beginner-to-advanced progression of stoichiometry questions: mole concept, Avogadro's constant, molar mass, balancing equations, mole ratios, limiting reagent, theoretical vs actual yield, concentrations/dilutions, precipitation reactions, simple titrations, and empirical/molecular formulas.

70 items — Study Guide with Answers

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1 **Which statement best defines 1 mole of a substance?**

- A The mass of 1 gram of the substance
- B **Exactly 6.02×10^{23} particles (atoms, molecules, or formula units) of that substance** ✓
- C The number of protons in the nucleus
- D The volume of 22.4 L of any substance
- E The number of neutrons in carbon-12

▶ **Explanation:** A mole is defined as a fixed number of entities: 6.02×10^{23}. It is not defined by 1 gram, and 22.4 L applies only to 1 mole of an ideal gas at STP.

2 **Avogadro's constant is most directly used to convert between:**

- A Mass (g) and volume (L)
- B **Moles and number of particles** ✓
- C Temperature (°C) and pressure (atm)
- D Electrons and neutrons
- E Density and molarity

▶ **Explanation:** Avogadro's constant (6.02×10^{23} mol^{-1}) converts moles number of particles. Mass conversions need molar mass, not Avogadro's constant alone.

3 **How many molecules are in 0.50 mol of CO2?**

- A 3.01×10^{22}
- B **3.01×10^{23}** ✓

C 6.02×10^{23}

D 1.20×10^{24}

E 0.50 molecules

▶ **Explanation:** Number of molecules = moles × Avogadro's constant = $0.50 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$ molecules.

4 **How many moles of water are in 18.0 g of H2O? (Mr(H2O) = 18.0)**

A 0.10 mol

B 0.50 mol

C **1.00 mol** ✓

D 2.00 mol

E 18.0 mol

▶ **Explanation:** Moles = mass ÷ molar mass = 18.0 g ÷ 18.0 g/mol = 1.00 mol.

5 **What is the mass of 0.250 mol of NaCl? (Mr(NaCl) = 58.5)**

A 7.31 g

B **14.6 g** ✓

C 29.3 g

D 58.5 g

E 0.250 g

▶ **Explanation:** Mass = moles × molar mass = 0.250 × 58.5 = 14.6 g (to 3 s.f.).

6 **A student says: "Mr(CO2) = 44, so the molar mass of CO2 is 44 g/mol." Which statement is correct?**

- A **The student is correct: molar mass in g/mol has the same number as Mr** ✓
- B The molar mass is 44 kg/mol, not g/mol
- C The molar mass is 44 g, not per mole
- D Mr cannot be used to get molar mass
- E The molar mass depends on temperature, so it cannot be determined

▶ **Explanation:** Relative molecular/formula mass (Mr) is a ratio with no units. The molar mass has units g/mol and numerically matches Mr (e.g., Mr = 44 → 44 g/mol).

7 **How many moles are in 2.0×10^{24} atoms of helium? (NA = 6.02×10^{23} mol—1)**

- A 0.332 mol
- B **3.32 mol** ✓
- C 6.02 mol
- D 12.0 mol
- E 1.20 mol

▶ **Explanation:** Moles = particles ÷ NA = $(2.0 \times 10^{24}) \div (6.02 \times 10^{23})$ 3.32 mol.

8 **How many moles of chloride ions (Cl—) are present in 0.10 mol of CaCl2 (assuming complete dissociation)?**

A 0.05 mol

B 0.10 mol

C **0.20 mol** ✓

D 0.30 mol

E 0.40 mol

▶ **Explanation:** Each formula unit of $CaCl_2$ contains 2 chloride ions. So 0.10 mol $CaCl_2$ contains $2 \times 0.10 = 0.20$ mol Cl^-.

9 **Which sample contains the greatest number of atoms?**

A 1.0 mol He

B 1.0 mol O_2

C 1.0 mol CO_2

D **1.0 mol CH_4** ✓

E 2.0 mol H_2

▶ **Explanation:** Count moles of atoms: He = 1 mol atoms; O_2 = 2 mol atoms; CO_2 = 3 mol atoms; CH_4 = 5 mol atoms; 2 mol H_2 = 4 mol atoms. CH_4 has the most atoms.

10 **At the same temperature and pressure, which pair contains the same number of molecules?**

A **1.0 L He(g) and 1.0 L N_2(g)** ✓

B 1.0 L He(g) and 2.0 L He(g)

C 1.0 L O_2(g) and 1.0 L CO_2(g), but only because both contain oxygen

D 2.0 L H_2(g) and 1.0 L H_2(g)

E 1.0 L He(g) and 1.0 L liquid water

▶ **Explanation:** Avogadro's law: equal volumes of gases at the same T and P contain equal numbers of molecules, regardless of gas identity. The key is equal volume and both being gases.

11 Which chemical equation is correctly balanced?

A $H_2 + O_2 \rightarrow H_2O$

B **$2H_2 + O_2 \rightarrow 2H_2O$** ✓

C $N_2 + H_2 \rightarrow NH_3$

D $2Na + Cl_2 \rightarrow NaCl$

E $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

▶ **Explanation:** A balanced equation has the same number of each atom on both sides. Only $2H_2 + O_2 \rightarrow 2H_2O$ balances H and O atoms correctly.

12 In the balanced equation $2H_2 + O_2 \rightarrow 2H_2O$, which interpretation is correct?

A 2 g of H_2 reacts with 1 g of O_2 to form 2 g of H_2O

B **2 moles of H_2 react with 1 mole of O_2 to form 2 moles of H_2O** ✓

C 2 molecules of H_2 react with 2 molecules of O_2 to form 1 molecule of H_2O

D The coefficients represent volumes of liquids, not gases or moles

E The coefficients must always be the same for all substances

▶ **Explanation:** Coefficients in a balanced equation represent ratios of particles and (most commonly used) ratios of moles. They are not mass ratios.

13 **If you multiply every coefficient in a balanced equation by 2, what changes?**

- A The equation becomes unbalanced
- B The mole ratios change
- C **The equation still represents the same reaction; only the amounts are scaled up** ✓
- D The substances in the reaction change
- E The reaction becomes faster automatically

▶ **Explanation:** Scaling all coefficients keeps ratios the same, so the chemistry is unchanged. You're just describing a larger (or smaller) amount of the same reaction.

14 **What is the coefficient of O_2 when propane combusts completely? ($C_3H_8 + O_2 \rightarrow CO_2 + H_2O$)**

- A 3
- B 4
- C **5** ✓
- D 8
- E 10

▶ **Explanation:** Balanced equation: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$. Oxygen atoms: 10 on each side.

15 **For the reaction $N_2 + 3H_2 \rightarrow 2NH_3$, how many moles of NH_3 can be produced from 6.0 mol of H_2 (with excess N_2)?**

- A 2.0 mol
- B 3.0 mol

C **4.0 mol** ✓

D 6.0 mol

E 12.0 mol

▶ **Explanation:** Mole ratio NH3:H2 = 2:3. So 6.0 mol H2 produces 6.0 × (2/3) = 4.0 mol NH3.

16 **In the reaction $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$, how many moles of CO are required to react with 0.50 mol Fe_2O_3?**

A 0.50 mol

B 1.0 mol

C **1.5 mol** ✓

D 2.0 mol

E 3.0 mol

▶ **Explanation:** The ratio CO:Fe_2O_3 is 3:1. So CO needed = 0.50 × 3 = 1.5 mol.

17 **Which balanced equation correctly represents the formation of aluminum oxide from aluminum and oxygen?**

A $Al + O_2 \rightarrow AlO_2$

B $2Al + O_2 \rightarrow 2AlO$

C **$4Al + 3O_2 \rightarrow 2Al_2O_3$** ✓

D $Al_2 + O_3 \rightarrow Al_2O_3$

E $2Al + 3O_2 \rightarrow Al_2O_3$

▶ **Explanation:** Al_2O_3 contains 2 Al and 3 O atoms. The balanced formation equation is $4Al + 3O_2 \rightarrow 2Al_2O_3$.

18 Why must chemical equations be balanced before doing stoichiometry calculations?

- A Because balancing makes the reaction faster
- B Because balancing changes the substances into safer forms
- C **Because balanced coefficients give the correct mole ratios and conserve atoms** ✓
- D Because balanced equations always have smaller numbers
- E Because unbalanced equations violate the octet rule

▶ **Explanation:** Stoichiometry relies on mole ratios from coefficients. Balancing ensures the same number of each atom on both sides (conservation of matter).

19 Calcium carbonate decomposes: $CaCO_3 \rightarrow CaO + CO_2$. If 2.0 mol of $CaCO_3$ decomposes completely, how many moles of CO_2 form?

- A 1.0 mol
- B **2.0 mol** ✓
- C 3.0 mol
- D 4.0 mol
- E 0.50 mol

▶ **Explanation:** The equation shows a 1:1 ratio between $CaCO_3$ and CO_2, so 2.0 mol $CaCO_3$ produces 2.0 mol CO_2.

20 **For 2Na + Cl2 → 2NaCl, you have 3.0 mol Na and 1.0 mol Cl2. What is the maximum amount of NaCl that can form?**

- A 1.0 mol
- B **2.0 mol** ✓
- C 3.0 mol
- D 4.0 mol
- E 6.0 mol

▶ **Explanation:** 1.0 mol Cl2 requires 2.0 mol Na and produces 2.0 mol NaCl. Since Na is in excess, Cl2 limits the product to 2.0 mol NaCl.

21 **For 2H2 + O2 → 2H2O, what mass of water forms when 4.0 g of H2 reacts completely with excess O2? (Mr(H2)=2.0, Mr(H2O)=18.0)**

- A 9.0 g
- B 18 g
- C **36 g** ✓
- D 72 g
- E 4.0 g

▶ **Explanation:** 4.0 g H2 = 4.0/2.0 = 2.0 mol H2. The ratio H2:H2O is 1:1, so 2.0 mol H2O forms. Mass = 2.0 × 18.0 = 36 g.

22 **Magnesium reacts with hydrochloric acid: Mg + 2HCl → MgCl2 + H2. If 24.0 g Mg reacts (Ar(Mg)=24.0), what volume of H2 is produced at STP (22.4 L/mol)?**

- A 11.2 L

B **22.4 L** ✓

C 44.8 L

D 2.24 L

E 224 L

▶ **Explanation:** 24.0 g Mg = 1.00 mol. The equation shows 1 mol Mg → 1 mol H2, so 1.00 mol H2 forms. At STP, 1 mol gas occupies 22.4 L.

23 CaCO3 → CaO + CO2. What mass of CO2 forms from 10.0 g CaCO3? (Mr(CaCO3)=100.0, Mr(CO2)=44.0)

A 2.20 g

B **4.40 g** ✓

C 10.0 g

D 22.0 g

E 44.0 g

▶ **Explanation:** 10.0 g CaCO3 = 10.0/100.0 = 0.100 mol. Ratio CaCO3:CO2 is 1:1, so 0.100 mol CO2 forms. Mass = 0.100 × 44.0 = 4.40 g.

24 Carbon burns: C + O2 → CO2. If 12.0 g of carbon reacts completely, what mass of CO2 is produced? (Ar(C)=12.0, Mr(CO2)=44.0)

A 12.0 g

B 22.0 g

C **44.0 g** ✓

D 88.0 g

E 56.0 g

▶ **Explanation:** 12.0 g C = 1.00 mol C. The ratio C:CO2 is 1:1, so 1.00 mol CO2 forms → 44.0 g.

25 **2Na + Cl2 → 2NaCl. If 11.5 g Na reacts with excess Cl2, what mass of NaCl forms? (Ar(Na)=23.0, Mr(NaCl)=58.5)**

A 11.5 g

B 14.6 g

C **29.3 g** ✓

D 58.5 g

E 117 g

▶ **Explanation:** Moles Na = 11.5/23.0 = 0.50 mol. The ratio Na:NaCl is 1:1 (2→2), so 0.50 mol NaCl forms. Mass = 0.50 × 58.5 = 29.3 g.

26 **For 2H2 + O2 → 2H2O, you start with 3.0 mol H2 and 1.0 mol O2. Which reactant is limiting?**

A H2 is limiting

B **O2 is limiting** ✓

C Both are limiting

D Neither is limiting; both are in excess

E Limiting reagent cannot be determined without masses

▶ **Explanation:** 1.0 mol O2 needs 2.0 mol H2. You have 3.0 mol H2, so O2 runs out first (limiting), leaving H2 in excess.

27 **For $2H_2 + O_2 \rightarrow 2H_2O$, you react 5.0 g H_2 with 32.0 g O_2. What mass of H_2O forms? ($M_r(H_2)=2.0$, $M_r(O_2)=32.0$, $M_r(H_2O)=18.0$)**

- A 18 g
- B **36 g** ✓
- C 45 g
- D 72 g
- E 90 g

▶ **Explanation:** Moles $H_2 = 5.0/2.0 = 2.5$ mol. Moles $O_2 = 32.0/32.0 = 1.0$ mol. 1.0 mol O_2 needs 2.0 mol H_2, so O_2 is limiting and forms 2.0 mol $H_2O \rightarrow 2.0 \times 18.0 = 36$ g.

28 **Using the same reaction as above ($2H_2 + O_2 \rightarrow 2H_2O$), if 5.0 g H_2 reacts with 32.0 g O_2, what mass of H_2 is left over?**

- A 0 g
- B 0.5 g
- C **1.0 g** ✓
- D 2.0 g
- E 3.0 g

▶ **Explanation:** O_2 is limiting (1.0 mol), so it consumes 2.0 mol H_2 = 4.0 g H_2. Starting with 5.0 g, leftover H_2 = 1.0 g.

29 **$2Al + 3Cl_2 \rightarrow 2AlCl_3$. You have 0.20 mol Al and 0.20 mol Cl_2. Which statement is correct?**

A Al is limiting and 0.20 mol $AlCl_3$ forms

B Cl_2 is limiting and 0.13 mol $AlCl_3$ forms ✓

C Cl_2 is limiting and 0.30 mol $AlCl_3$ forms

D Neither is limiting; both are exactly consumed

E Al is limiting and 0.30 mol $AlCl_3$ forms

▶ **Explanation:** 0.20 mol Cl_2 would require $(2/3)\times0.20 = 0.133$ mol Al, so Cl_2 is limiting. Product moles $AlCl_3 = (2/3)\times0.20 = 0.133$ mol (0.13 mol).

30 $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. If you start with 0.50 mol CH_4 and 1.00 mol O_2, what is true?

A CH_4 is limiting

B O_2 is limiting

C Both are limiting (both run out first)

D Neither is in excess; both are completely consumed ✓

E No reaction occurs because the coefficients are not equal

▶ **Explanation:** The ratio required is 1 mol CH_4 per 2 mol O_2. 0.50 mol CH_4 requires exactly 1.00 mol O_2, so it's a perfect stoichiometric mixture: both are used up.

31 Which statement best defines the limiting reactant?

A The reactant with the highest molar mass

B The reactant present in the greatest mass

C The reactant that is completely used up first and determines the maximum amount of product ✓

D The reactant written first in the equation

E The reactant that never gets consumed

▶ **Explanation:** The limiting reactant is the one that runs out first according to the balanced mole ratios, setting the cap on how much product can form.

32 A reaction has a theoretical yield of 20.0 g but an actual yield of 15.0 g. What is the percent yield?

A 35%

B 60%

C **75%** ✓

D 85%

E 133%

▶ **Explanation:** Percent yield = (actual ÷ theoretical) × 100 = (15.0/20.0)×100 = 75%.

33 Which is the best overall reason why actual yield is often less than theoretical yield in real experiments?

A Atoms disappear during reactions

B The limiting reactant changes into an excess reactant

C **Side reactions, incomplete reaction, and losses during separation/purification** ✓

D Balanced equations are never correct

E Avogadro's constant changes with temperature

▶ **Explanation:** Real reactions may not go to completion, competing reactions may occur, and products can be lost during filtering, transferring, or purification—so actual yield is often lower.

34 **For $N_2 + 3H_2 \rightarrow 2NH_3$, you start with 2.0 mol N_2 and 3.0 mol H_2. Which statement is correct?**

- A N2 is limiting and 4.0 mol NH3 forms
- B **H2 is limiting and 2.0 mol NH3 forms ✓**
- C H2 is limiting and 3.0 mol NH3 forms
- D Neither is limiting; both are fully consumed
- E N2 is limiting and 2.0 mol NH3 forms

▶ **Explanation:** 2.0 mol N2 would require 6.0 mol H2, but only 3.0 mol H2 is available, so H2 is limiting. NH3 formed = $3.0 \times (2/3) = 2.0$ mol.

35 **$2KClO_3 \rightarrow 2KCl + 3O_2$. If 24.5 g $KClO_3$ decomposes completely, what volume of O_2 is produced at STP? (Mr($KClO_3$)=122.5, molar gas volume = 22.4 L/mol)**

- A 2.24 L
- B 4.48 L
- C **6.72 L ✓**
- D 11.2 L
- E 22.4 L

▶ **Explanation:** Moles KClO3 = $24.5/122.5 = 0.200$ mol. O2 moles = $0.200 \times (3/2) = 0.300$ mol. Volume = $0.300 \times 22.4 = 6.72$ L.

36 **$2KClO_3 \rightarrow 2KCl + 3O_2$. If 0.10 mol O_2 is produced, how many moles of $KClO_3$ decomposed?**

- A 0.050 mol
- B **0.067 mol** ✓
- C 0.10 mol
- D 0.15 mol
- E 0.20 mol

▶ **Explanation:** From the ratio $KClO_3$:O_2 = 2:3. So moles $KClO_3$ = (2/3) × 0.10 = 0.0667 mol (0.067 mol).

37 **$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$. If 0.50 mol Ca reacts completely with excess water, what mass of $Ca(OH)_2$ forms? (Mr($Ca(OH)_2$)=74.0)**

- A 18.5 g
- B **37.0 g** ✓
- C 74.0 g
- D 148 g
- E 0.50 g

▶ **Explanation:** The ratio Ca:$Ca(OH)_2$ is 1:1, so 0.50 mol $Ca(OH)_2$ forms. Mass = 0.50 × 74.0 = 37.0 g.

38 **$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$. You react 10.0 g $CaCO_3$ with 10.0 g HCl. Which statement is correct? (Mr($CaCO_3$)=100.0, Mr(HCl)=36.5, Mr(CO_2)=44.0)**

A HCl is limiting and 2.2 g CO_2 forms

B CaCO3 is limiting and 4.4 g CO2 forms ✓

C CaCO3 is limiting and 8.8 g CO2 forms

D Neither is limiting; both are used completely

E HCl is limiting and 4.4 g CO2 forms

▶ **Explanation:** Moles CaCO3 = 10.0/100.0 = 0.100 mol. Moles HCl = 10.0/36.5 = 0.274 mol. Needed HCl = 2×0.100 = 0.200 mol, so HCl is in excess and CaCO3 is limiting. CO2 moles = 0.100 → mass = 0.100×44.0 = 4.4 g.

39 In the reaction above, the theoretical CO2 mass is 4.4 g, but you collect only 3.5 g. What is the percent yield?

A 50%

B 70%

C 79.5% ✓

D 95%

E 125%

▶ **Explanation:** Percent yield = (3.5/4.4)×100 79.5%.

40 A student calculates a percent yield of 120% for a product. Which is the most likely explanation?

A The balanced equation must be wrong because yields cannot exceed 100% under any circumstances

B The product likely contained impurities or solvent/water, making the measured mass too high ✓

C Atoms were created during the reaction

D Avogadro's constant increased during the experiment

E The limiting reactant became unlimited

▶ **Explanation:** A yield over 100% usually indicates measurement issues: product not dry, contamination, or impurities included in the mass. It doesn't mean atoms were created.

41 Molarity (concentration) is defined as:

A Mass of solute ÷ mass of solution

B **Moles of solute ÷ volume of solution in liters** ✓

C Volume of solute ÷ moles of solution

D Mass of solute ÷ volume of solute

E Number of particles ÷ volume in mL

▶ **Explanation:** Molarity (M) = moles of solute per liter of solution (mol/L).

42 What is the molarity of a solution made by dissolving 0.50 mol NaCl in 2.0 L of solution?

A 0.10 M

B **0.25 M** ✓

C 0.50 M

D 1.0 M

E 2.5 M

▶ **Explanation:** M = n/V = 0.50 mol ÷ 2.0 L = 0.25 M.

43 **How many moles of HCl are in 250 mL of 0.20 M HCl?**

- A 0.0050 mol
- B **0.050 mol** ✓
- C 0.20 mol
- D 0.80 mol
- E 50 mol

▶ **Explanation:** Convert mL to L: 250 mL = 0.250 L. Moles = M×V = 0.20 × 0.250 = 0.050 mol.

44 **How many grams of NaOH are needed to make 500 mL of 0.10 M NaOH? (Mr(NaOH)=40.0)**

- A 0.50 g
- B **2.0 g** ✓
- C 4.0 g
- D 20 g
- E 40 g

▶ **Explanation:** Moles needed = M×V = 0.10 × 0.500 = 0.050 mol. Mass = 0.050 × 40.0 = 2.0 g.

45 **You dilute 100 mL of 2.0 M HCl to a final volume of 500 mL. What is the new concentration?**

- A 0.10 M

B **0.40 M** ✓

C 1.0 M

D 2.5 M

E 10 M

▶ **Explanation:** Use C1V1 = C2V2 (volumes in L). C2 = 2.0×0.100 / 0.500 = 0.40 M.

46 Which statement is always true when you dilute a solution by adding water (no reaction occurs)?

A The number of moles of solute increases

B **The number of moles of solute stays the same, but concentration decreases** ✓

C The molar mass of the solute changes

D The solute turns into a different chemical

E The volume decreases

▶ **Explanation:** Dilution adds solvent, increasing volume. The amount (moles) of solute stays constant, so concentration (moles/volume) decreases.

47 AgNO3(aq) + NaCl(aq) → AgCl(s) + NaNO3(aq). If you mix 50.0 mL of 0.10 M AgNO3 with 50.0 mL of 0.10 M NaCl, how many moles of AgCl form?

A 0.0010 mol

B 0.0025 mol

C **0.0050 mol** ✓

D 0.010 mol

E 0.100 mol

▶ **Explanation:** Moles $AgNO3$ = 0.0500 L×0.10 = 0.0050 mol. Moles NaCl = 0.0500×0.10 = 0.0050 mol. 1:1 reaction, so 0.0050 mol AgCl forms.

48 **AgNO3(aq) + NaCl(aq) → AgCl(s) + NaNO3(aq). If you mix 50.0 mL of 0.10 M AgNO3 with 100 mL of 0.020 M NaCl, how many moles of AgCl form?**

- A 0.0010 mol
- B **0.0020 mol** ✓
- C 0.0050 mol
- D 0.010 mol
- E 0.020 mol

▶ **Explanation:** Moles AgNO3 = 0.0500×0.10 = 0.0050 mol. Moles NaCl = 0.100×0.020 = 0.0020 mol. NaCl is limiting (1:1), so AgCl formed = 0.0020 mol.

49 **How many grams of NaCl are needed to prepare 250 mL of 0.50 M NaCl? (Mr(NaCl)=58.5)**

- A 1.46 g
- B 3.66 g
- C **7.31 g** ✓
- D 14.6 g
- E 29.3 g

▶ **Explanation:** Moles needed = M×V = 0.50×0.250 = 0.125 mol. Mass = 0.125×58.5 = 7.31 g.

50 **How many formula units are in 0.10 mol of NaCl? (NA = 6.02×10^{23} mol−1)**

A **6.02×10^{22}** ✓

B 6.02×10^{23}

C 3.01×10^{23}

D 1.20×10^{24}

E 0.10×10^{23}

▶ **Explanation:** Particles = moles × NA = $0.10 \times 6.02 \times 10^{23} = 6.02 \times 10^{22}$ formula units.

51 **HCl + NaOH → NaCl + H2O. 25.0 mL of HCl is neutralized by 30.0 mL of 0.100 M NaOH. What is the concentration of HCl?**

A 0.0400 M

B 0.0800 M

C **0.120 M** ✓

D 0.300 M

E 0.400 M

▶ **Explanation:** Moles NaOH = 0.0300 L×0.100 = 0.00300 mol. Ratio 1:1, so moles HCl = 0.00300 mol. [HCl] = 0.00300/0.0250 = 0.120 M.

52 **H2SO4 + 2NaOH → Na2SO4 + 2H2O. If 20.0 mL of 0.50 M NaOH is required to neutralize some H2SO4, how many moles of H2SO4 were neutralized?**

A 0.010 mol

B **0.0050 mol** ✓

C 0.020 mol

D 0.040 mol

E 0.0025 mol

▶ **Explanation:** Moles NaOH = 0.0200×0.50 = 0.0100 mol. The ratio H2SO4:NaOH is 1:2, so moles H2SO4 = 0.0100/2 = 0.0050 mol.

53 H2SO4 + 2NaOH → Na2SO4 + 2H2O. What volume of 0.100 M NaOH is needed to completely neutralize 25.0 mL of 0.200 M H2SO4?

A 25.0 mL

B 50.0 mL

C **100 mL** ✓

D 200 mL

E 400 mL

▶ **Explanation:** Moles H2SO4 = 0.0250×0.200 = 0.00500 mol. Need 2× as many moles NaOH = 0.0100 mol. Volume NaOH = 0.0100/0.100 = 0.100 L = 100 mL.

54 Ca(OH)2 + 2HCl → CaCl2 + 2H2O. How many moles of HCl are needed to neutralize 0.010 mol Ca(OH)2?

A 0.005 mol

B 0.010 mol

C **0.020 mol** ✓

D 0.030 mol

E 0.040 mol

▶ **Explanation:** The mole ratio Ca(OH)2:HCl is 1:2, so 0.010 mol Ca(OH)2 needs 2×0.010 = 0.020 mol HCl.

55 **How many moles of OH— are required to fully neutralize 0.10 mol of H2SO4?**

- A 0.05 mol
- B 0.10 mol
- C **0.20 mol** ✓
- D 0.30 mol
- E 0.40 mol

▶ **Explanation:** H2SO4 is diprotic: each mole can donate 2 moles of H^+. Full neutralization requires 2 moles OH— per mole H2SO4 → 0.10×2 = 0.20 mol OH—.

56 **How many moles of NaOH are needed to fully neutralize 1.0 mol of H3PO4 (complete neutralization)?**

- A 1.0 mol
- B 2.0 mol
- C **3.0 mol** ✓
- D 4.0 mol
- E 6.0 mol

▶ **Explanation:** H3PO4 is triprotic (3 acidic H). Complete neutralization requires 3 moles OH— (thus 3 moles NaOH) per mole H3PO4.

57 **$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$. What volume of 0.200 M HCl is needed to neutralize 25.0 mL of 0.100 M Na_2CO_3?**

- A 12.5 mL
- B **25.0 mL** ✓
- C 50.0 mL
- D 100 mL
- E 200 mL

▶ **Explanation:** Moles Na_2CO_3 = 0.0250×0.100 = 0.00250 mol. Need 2× moles HCl = 0.00500 mol. Volume HCl = 0.00500/0.200 = 0.0250 L = 25.0 mL.

58 **HCl + NaOH → NaCl + H_2O. If 10.0 mL of 0.200 M HCl is neutralized by 25.0 mL of NaOH, what is the NaOH concentration?**

- A 0.0400 M
- B 0.0600 M
- C **0.0800 M** ✓
- D 0.120 M
- E 0.200 M

▶ **Explanation:** Moles HCl = 0.0100×0.200 = 0.00200 mol. 1:1 reaction, so moles NaOH = 0.00200 mol. [NaOH] = 0.00200/0.0250 = 0.0800 M.

59 **In a titration, a student overshoots the endpoint (adds too much base) and still records that final, larger volume as if it were the equivalence volume. How does this affect the calculated concentration of the acid (assuming base concentration is known and correct)?**

- A **Calculated acid concentration is too high** ✓
- B Calculated acid concentration is too low
- C Calculated acid concentration is unchanged
- D The calculation becomes impossible
- E Calculated acid concentration becomes zero

▶ **Explanation:** Using too large a base volume makes the calculated moles of base (and therefore moles of acid) too large, so the acid concentration is overestimated.

60 **A burette was not rinsed with the NaOH solution before filling; it still contained some distilled water. The student then uses the labeled NaOH concentration in calculations. How will the calculated acid concentration be affected?**

- A **Too high, because the NaOH delivered was actually more dilute than assumed** ✓
- B Too low, because the NaOH delivered was actually more concentrated than assumed
- C Unchanged, because water does not matter in titrations
- D Exactly correct, because dilution cancels out perfectly
- E Impossible to predict without knowing the acid formula

▶ **Explanation:** Water left in the burette dilutes the NaOH. More volume is needed to neutralize the acid, but if you still use the higher labeled NaOH concentration, you overestimate moles base and overestimate acid concentration.

61 **A compound is 40.0% C, 6.7% H, and 53.3% O by mass. What is the empirical formula? (Ar: C=12, H=1, O=16)**

- A CH4O
- B **CH2O** ✓

C $C_2H_4O_2$

D C_2H_6O

E CHO_2

▶ **Explanation:** Assume 100 g: C=40/12=3.33 mol, H=6.7/1=6.7 mol, O=53.3/16=3.33 mol. Divide by 3.33 → $C_1H_2O_1$ → CH_2O.

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62 **The empirical formula of a compound is CH_2O (empirical mass = 30 g/mol). If its molar mass is 180 g/mol, what is the molecular formula?**

A CH_2O

B $C_2H_4O_2$

C $C_3H_6O_3$

D **$C_6H_{12}O_6$** ✓

E $C_{12}H_{24}O_{12}$

▶ **Explanation:** Factor = 180/30 = 6. Multiply subscripts by 6: $(CH_2O)_6$ = $C_6H_{12}O_6$.

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63 **A sample contains 0.20 mol of nitrogen atoms and 0.60 mol of hydrogen atoms. What is the simplest formula (empirical) for the compound?**

A NH

B NH_2

C **NH_3** ✓

D N_2H_3

E N_3H

▶ **Explanation:** Divide by the smaller amount: N:H = 0.20:0.60 = 1:3, giving NH_3.

64 **A 2.495 g sample of $CuSO_4 \cdot xH_2O$ is heated to constant mass and becomes 1.595 g of anhydrous $CuSO_4$. What is x? (Ar: Cu=63.5, S=32.0, O=16.0, H=1.0)**

- A 2
- B 3
- C 4
- D **5** ✓
- E 6

▶ **Explanation:** Water lost = 2.495−1.595 = 0.900 g → moles H_2O = 0.900/18.0 = 0.0500 mol. Mr($CuSO_4$)=63.5+32.0+64.0=159.5, so moles $CuSO_4$ = 1.595/159.5 = 0.0100 mol. Ratio H_2O:$CuSO_4$ = 0.0500:0.0100 = 5:1 → x=5.

65 **$BaCl_2$(aq) + Na_2SO_4(aq) → $BaSO_4$(s) + 2NaCl(aq). If you mix 100 mL of 0.10 M $BaCl_2$ with 100 mL of 0.050 M Na_2SO_4, how many moles of $BaSO_4$ form?**

- A 0.010 mol
- B 0.0075 mol
- C **0.0050 mol** ✓
- D 0.0025 mol
- E 0.0010 mol

▶ **Explanation:** Moles $BaCl_2$ = 0.100×0.10 = 0.010 mol. Moles Na_2SO_4 = 0.100×0.050 = 0.0050 mol. $BaSO_4$ forms 1:1 with SO_4^{2-} source, so Na_2SO_4 is limiting → 0.0050 mol $BaSO_4$ forms.

66 **$2KClO_3 \rightarrow 2KCl + 3O_2$. If 3.36 L of O_2 is collected at STP, what mass of $KClO_3$ decomposed? (Mr($KClO_3$)=122.5, molar gas volume = 22.4 L/mol)**

- A 4.08 g
- B 8.17 g
- C **12.25 g** ✓
- D 24.5 g
- E 36.8 g

▶ **Explanation:** Moles O_2 = 3.36/22.4 = 0.150 mol. Moles $KClO_3$ = (2/3)×0.150 = 0.100 mol. Mass = 0.100×122.5 = 12.25 g.

67 **$N_2 + 3H_2 \rightarrow 2NH_3$. At the same temperature and pressure, you mix 10 L N_2 with 20 L H_2. Assuming complete reaction, what volume of NH_3 forms?**

- A 6.7 L
- B 10 L
- C **13.3 L** ✓
- D 20 L
- E 30 L

▶ **Explanation:** Gas volumes follow mole ratios at the same T and P. 3 volumes H_2 produce 2 volumes NH_3. With 20 L H_2 (limiting), NH_3 volume = (2/3)×20 = 13.3 L.

68 **What is the mass percent of oxygen in CO_2? (Ar: C=12, O=16)**

- A 27.3%
- B 50.0%

C **72.7%** ✓

D 80.0%

E 88.0%

▶ **Explanation:** Mr(CO2)=12+32=44. Oxygen mass = 32. Percent O = (32/44)×100 = 72.7%.

69 **How many atoms are there in 0.20 mol of CaCO3? (NA = 6.02×10^{23} mol−1)**

A 1.20×10^{23} atoms

B 6.02×10^{22} atoms

C **6.02×10^{23} atoms** ✓

D 3.01×10^{23} atoms

E 1.20×10^{24} atoms

▶ **Explanation:** Each CaCO3 formula unit has 5 atoms (Ca + C + 3O). 0.20 mol CaCO3 contains 0.20×5 = 1.00 mol atoms. 1.00 mol atoms = 6.02×10^{23} atoms.

70 **How many moles of oxygen atoms are contained in 1.0 mol of glucose (C6H12O6)?**

A 1.0 mol

B 3.0 mol

C **6.0 mol** ✓

D 12.0 mol

E 18.0 mol

▶ **Explanation:** Each glucose molecule contains 6 oxygen atoms. Therefore, 1.0 mol of glucose molecules contains 6.0 mol of oxygen atoms.