

CANADIAN CHEMISTRY CONTEST

CHEMISTRY

TOPIC QUESTIONS

King



5A Solutions and Stoichiometry



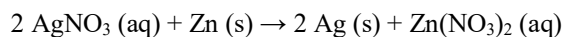
KingCh



- 1) What mass of cobalt (II) chloride hexahydrate must be used in order to make 500.0 mL of a solution that has a chloride ion concentration of $[Cl^-] = 0.300 \text{ mol L}^{-1}$?
- A) 9.74 g B) 17.8 g C) 35.7 g D) 143 g E) 150 g
- 3) A student combines 25.00 mL of a 0.125 mol L^{-1} solution of potassium iodide KI with 10.00 mL of a 0.250 mol L^{-1} solution of lead (II) nitrate $Pb(NO_3)_2$. What mass of precipitate will be formed?
- A) 0.316 g B) 0.720 g C) 0.980 g D) 1.15 g E) 1.44 g

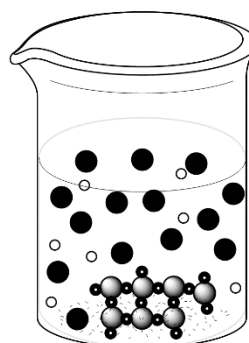
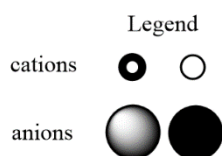
CCC 2021

- 1) 15 mL of 0.25 mol L^{-1} aqueous silver nitrate reacts with 0.10 g of zinc as follows:



What mass of silver metal should the reaction produce?

- A) 0.16 g B) 0.20 g C) 0.33 g D) 0.40 g E) 0.81 g
- 3) A student combines 100 mL of two clear, equimolar, colourless solutions and observes a solid white precipitate form at the bottom of the beaker. A representation of the resultant particles in the beaker is in the diagram below. Which combination of reactants would best align with the information provided and diagram of resultant particles in the beaker?
- A) lead (II) nitrate (aq) + potassium chloride (aq)
B) zinc nitrate (aq) + sodium phosphate (aq)
C) nickel (II) nitrate (aq) + lithium bromide (aq)
D) copper (II) nitrate (aq) + sodium hydroxide (aq)
E) silver nitrate (aq) + magnesium sulfate (aq)





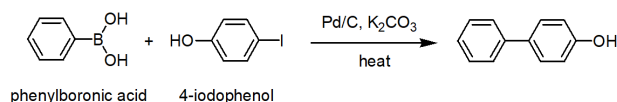
10) When a sample of an unknown compound with a formula of C_xH_y combusts with an excess amount of oxygen, the reaction produces 132.001 g of carbon dioxide and 72.064 g of water. Based on the information given, this unknown compound is:

- A) methane B) ethane C) propane D) butane E) octane

21) The *reaction mass efficiency* (RME) helps a student determine how much reactant material a product contains at the end of a chemical reaction. RME is calculated as follows:

$$\text{reaction mass efficiency} = \frac{\text{mass of desired product}}{\text{(total input mass - mass of recycled material)}} \times 100\%$$

0.205 moles of phenylboronic acid ($C_6H_7BO_2$) was reacted with 0.205 moles of 4-iodophenol (C_6H_5IO) and 0.615 moles of potassium carbonate to form 0.185 moles of 4-phenylphenol (shown below). 300 mg of catalytic palladium on carbon was used and completely recycled.



- A) 18.4 % B) 20.3 % C) 24.2 % D) 25.5% E) 35.1 %

12) A mixture of ethanol and nitric acid, called nital, is an industrial etching agent. A student prepared a 20.0 mL solution of nital using 0.70 mL of nitric acid of unknown concentration and 19.3 mL of 98% ethanol. The student determined by titration that the final concentration of nitric acid in the nital etching agent was 4.0 % by mass. The density of 98% ethanol was 0.79 g mL^{-1} and the density of the unknown concentration of aqueous HNO_3 was 1.4 g mL^{-1} . What was the **original** concentration of HNO_3 , in w/w, in the 0.70 mL reagent the student used for the nital solution preparation?

- A) 63% B) 66% C) 70% D) 73% E) 93%

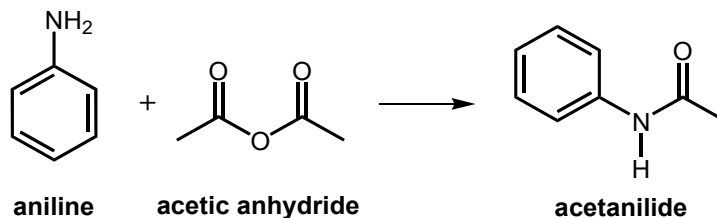
CCC 2020

1) A solution is 0.0240 mol L^{-1} KI and 0.0146 mol L^{-1} MgI_2 . What volume of water should be added to 100.0 mL of this solution to produce a solution with $[I^-]$ concentration of 0.0500 mol L^{-1} ?

- A) 106.4 mL B) 53.2 mL C) 26.6 mL D) 13.3 mL E) 6.4 mL

- 3) Health Canada recommends that women between the ages of 12 and 45 consume 400 micrograms of folic acid ($C_{19}H_{19}N_7O_6$) per day, which reduces the risk of neural tube defects during pregnancy. How many moles of folic acid are equivalent to 400 micrograms?
- A) 1.10 mmol B) 0.177 mol C) 0.906 mol
 D) 0.906 mmol E) 9.06×10^{-7} mol
- 4) An unknown amino acid contains 9.5 % nitrogen by mass as determined by elemental analysis. Which of the following could be the unknown amino acid?
- A) arginine $C_6H_{14}N_4O_2$ B) cysteine $C_3H_7NO_2S$
 C) histidine $C_6H_9N_3O_2$ D) glutamic acid $C_5H_9NO_4$
 E) glycine $C_2H_5NO_2$
- 12) Lead (II) sulfate can decompose into lead (II) sulfite and oxygen gas when heated. If the reaction generates 2.25 g of oxygen gas, what mass of lead (II) sulfate reacted? Assume 100% yield in this reaction.
- A) 42.6 g B) 21.3 g C) 20.2 g D) 10.7 g E) 4.50 g

- 16) The compound acetanilide is important in the industrial synthesis of several dyes. Acetanilide (mol. wt. = 135.16) can be made in the laboratory by a reaction between aniline and excess acetic anhydride which has a yield of 61.5%:



Aniline and acetic anhydride are both liquids which have densities of 1.219 g mL^{-1} and 1.082 g mL^{-1} respectively.

What volume of aniline was used in this reaction if the recorded mass of acetanilide product was 7.14 g?

- A) 4.03 mL B) 9.75 mL C) 4.92 mL
 D) 5.99 mL E) 6.56 mL
- 17) One of the Twelve Principles of Green Chemistry is that “synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product”. One way to consider this is to calculate the *atom economy* (AE) of a chemical reaction where AE is defined as follows:

$$\text{atom economy} = \frac{\text{molecular mass of desired product}}{\text{molecular mass of all reactants}} \times 100\%$$

The atom economy of the reaction in the previous question (#16) is:

- A) 61.5% B) 69.2% C) 100% D) 68.9% E) 74.4%



2) Vitamin C ($C_6H_8O_6$) supplements often come in 500 mg tablets. If a person consumes one 500 mg tablet of Vitamin C, how many moles of Vitamin C would they be consuming?

- A) 2.84×10^{-3} B) 8.81×10^{-2} C) 1.00
D) 2.84 E) 88.1

3) What is the mole percent of a solution of ethanol (C_2H_5OH) which consists of 71.0 g of ethanol for every 12.8 g of water present?

- A) 2.17 % B) 12.3 % C) 31.6 %
D) 68.4 % E) 84.7 %

5) A compound is composed of element X and hydrogen. Analysis shows the compound to be 79.89 % X by mass, with three times as many hydrogen atoms as X atoms per molecule. Which element is element X?

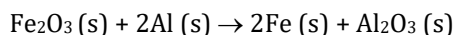
- A) He B) C C) N D) P E) S

19) A quantity of solid material weighing 6.445 g was obtained from a hazardous waste facility. A 1.545 g sample of this material was analyzed for barium content by dissolving in water and then adding sodium sulfate. The insoluble barium sulfate precipitate was dried, and a total of 73.8 mg of $BaSO_4$ was collected. What percentage by mass of the sample is barium?

- A) 0.281 % B) 0.674 % C) 2.81 % D) 4.02 % E) 6.74 %

CCC 2018

4) The exothermic thermite reaction between iron (III) oxide and aluminum metal occurs as follows:



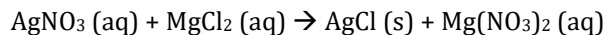
If 8.0 g of iron (III) oxide is combined with 5.4 g of aluminum metal, what mass of iron metal will be produced?

- A) 2.8 g B) 5.6 g C) 8.0 g D) 11 g E) 14 g

10) The *molality* (m) of a solution is defined as the number of moles of solute per kilogram of solvent. Lauryl alcohol ($C_{12}H_{26}O$) is prepared from coconut oil and is used to make sodium lauryl sulfate, a synthetic detergent. What is the molality of a solution of 17.1 g lauryl alcohol dissolved in 3.21 moles of ethanol (C_2H_6O)?

- A) 0.310 m B) 0.621 m C) 0.842 m D) 1.41 m E) 2.52 m

- 16) When aqueous magnesium chloride is added to a solution of silver nitrate, silver chloride is precipitated according to the following **unbalanced** chemical equation:



If excess magnesium chloride is added to the silver nitrate solution, which of the following diagrams best depicts the balanced chemical reaction after it has gone to completion?

Legend

● = Ag ⁺	○ = NO ₃ ⁻
● = Mg ²⁺	● = Cl ⁻

A

B

C

D

E

- 17) The *process mass intensity* (PMI) allows chemists to calculate how much material is used when generating a target amount of product in a chemical reaction. PMI is expressed as follows:

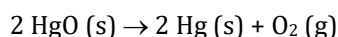
$$\text{PMI} = [(\text{mass of all input materials}) / (\text{mass of desired product})]$$

To synthesize moclobemide, an anti-depressant pharmaceutical, 0.00381 moles of 4-(2-aminoethyl)morpholine (C₆H₁₄N₂O) is dissolved in 20.0 mL of triethylamine (density: 0.726 g mL⁻¹) and 0.00384 moles of 4-chlorobenzoyl chloride (C₇H₄Cl₂O) is added. After rapid stirring for 30 minutes, 10.0 mL (density: 1.00 g mL⁻¹) of water is added followed by 10.0 mL of dichloromethane (density: 1.325 g mL⁻¹) and then the mixture transferred to a separatory funnel. After extraction, the dichloromethane is dried with 5.0 g of magnesium sulfate. At the end of the process, 0.826 g of pure moclobemide is recovered.

The PMI for this reaction is:

- A) 43.8 B) 47.1 C) 49.3 D) 53.2 E) 55.9

- 18) A closed 600.0 mL flask contains solid mercuric oxide and air initially at 21.0°C and 101.3 kPa. When heated, mercuric oxide decomposes completely according to the reaction:



After heating, the flask is at a temperature of 75.2°C and has a pressure of 205.5 kPa. What mass of mercury metal is in the flask when the reaction is complete?

- A) 7.11 g B) 4.33 g C) 3.56 g D) 17.1 g E) 8.66 g

22) When solid tin is added to a solution of silver nitrate, a single displacement reaction occurs to generate silver metal.

If 1.2 g of tin is added to 50 mL of 0.20 M silver nitrate solution, which of the following diagrams best describes the reaction once it has gone to completion?

Legend

● = Ag ⁺	■ = Ag (s)
● = Sn ²⁺	■ = Sn (s)
○ = NO ₃ ⁻	

A

B

C

D

E

CCC 2017

2) A 0.48 g piece of magnesium metal is placed in hydrochloric acid. Assuming the hydrochloric acid is in excess and the magnesium reacts completely, how many grams of hydrogen gas are produced?

- A) 0.010 g B) 0.040 g C) 0.080 g
 D) 0.48 g E) 0.96 g

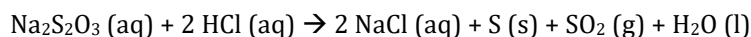
6) The limit for lead in drinking water is 0.015 ppm according to the Environmental Protection Agency (EPA). A 100.0 mL sample of well water tested for dissolved Pb²⁺ with a saturated potassium iodide solution produced 1.7 mg of yellow lead iodide precipitate. How many times higher than the EPA limit was the concentration of lead in the well water?

- A) 110 times B) 1100 times C) 510 times D) 700 times E) 51 times

7) A common method for cleaning up an acid spill is to spread sodium carbonate over the spill to neutralize it. If 50.0 mL of 0.75 mol L⁻¹ HCl spilled on the countertop, what is the minimum amount of sodium carbonate required to neutralize the spill?

- A) 1.6 g B) 1.9 g C) 2.0 g D) 3.1 g E) 4.0 g

13) A student performs the following reaction to make solid sulfur:



The student records the following data at the start of the reaction:

	Concentration (mol L ⁻¹)	Volume (mL)
Na ₂ S ₂ O ₃ (aq)	0.45	130
HCl (aq)	0.15	400

If the student recovers 0.89 g of solid sulfur from the experiment, what is the % yield of the reaction?

- A) 46% B) 48% C) 75% D) 89% E) 93%

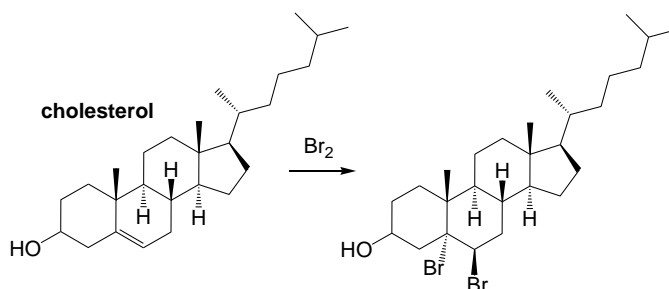
11) Penicillamine is an important organic compound used in the treatment of rheumatoid arthritis. One molecule of penicillamine contains a single sulfur atom and the weight percentage of sulfur in penicillamine is 21.49%. What is the molecular weight of penicillamine in g mol⁻¹?

- A) 85.40 B) 101.3 C) 125.2 D) 137.6 E) 149.2

17) The metric known as *reaction mass efficiency* (RME) provides a way to assess how much reactant material ends up in a desired product at the end of a chemical reaction. One way of expressing RME is as follows:

$$\text{reaction mass efficiency} = \frac{\text{mass of desired product}}{(\text{total input mass} - \text{mass of recycled material})}$$

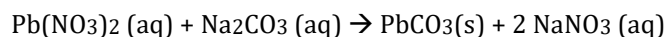
0.115 moles of cholesterol (C₂₇H₄₆O) was reacted with 0.365 moles of molecular bromine to form 0.102 moles of dibromocholesterol in an addition reaction (shown below). It was possible to recover and recycle 0.151 moles of molecular bromine from the reaction mixture.



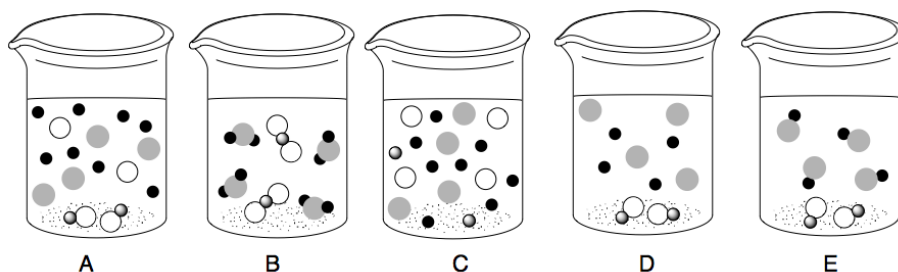
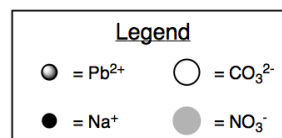
What is the percentage reaction mass efficiency for this process?

- A) 43.3 % B) 54.3% C) 70.9% D) 84.6 % E) 89.1%

18) Solid lead carbonate precipitate can be formed from mixing aqueous lead nitrate and sodium carbonate:



If 360 mL of 0.15 mol L^{-1} sodium carbonate was combined with 45 mL of 0.60 mol L^{-1} lead nitrate, which of the following diagrams best describes the system once it has gone to completion?

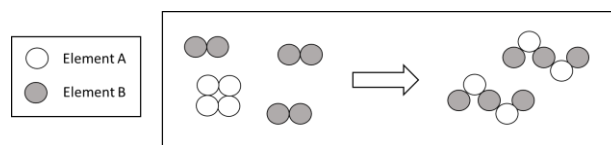


23) A gaseous anesthetic with an unknown molecular formula is 85.63% carbon and 14.37% hydrogen by mass. What is the molecular formula of the unknown if 0.45 L of the compound combusts with excess oxygen at 120.0°C at 72.93 kPa to form 2.70 L of an equimolar mixture of carbon dioxide and water vapour?

- A) C_3H_6 B) C_4H_8 C) C_5H_{10} D) C_6H_{12} E) C_7H_{14}

CCC 2016

2. What is the correctly balanced form of the chemical reaction depicted in the figure below?



- A) $4 \text{ A} + 6 \text{ B} \rightarrow \text{A}_4\text{B}_6$
 B) $\text{A}_4 + \text{B}_6 \rightarrow \text{A}_4\text{B}_6$
 C) $\text{A}_4 + 3 \text{ B}_2 \rightarrow 2 \text{ A}_2 + 2 \text{ B}_3$
 D) $\text{A}_4 + 3 \text{ B}_2 \rightarrow 2 \text{ A}_2\text{B}_3$
 E) $4 \text{ A} + 3 \text{ B}_2 \rightarrow 2 \text{ A}_2\text{B}_3$



3. One component of gastric (stomach) fluid is hydrochloric acid (HCl). Baking soda (NaHCO_3) will neutralize HCl according to the reaction:
 $\text{NaHCO}_3(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

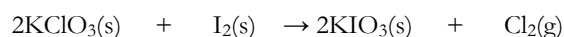
How many grams of CO_2 are produced when 300 mL of 1.22 mol L^{-1} HCl react with 175 mL of 1.55 mol L^{-1} NaHCO_3 ?

- A) 9.89 g B) 10.5 g C) 11.9 g D) 14.4 g E) 16.1 g

5. Dapsone is the active ingredient in Aczone™ gel, a treatment for adult acne. Each gram of Aczone gel contains 50 mg of dapsone (molecular weight 248.3 g mol^{-1}). The dapsone content of a 10.0 g sample of Aczone was analyzed and found to be composed of 290.3 mg carbon, 64.5 mg sulphur, 56.4 mg nitrogen and 24.4 mg hydrogen with the remaining mass being oxygen. What is the molecular formula of dapsone?

- A) $\text{C}_{12}\text{H}_{10}\text{NOS}_2$ B) $\text{C}_{10}\text{H}_8\text{N}_4\text{O}_2\text{S}$ C) $\text{C}_{11}\text{H}_8\text{N}_2\text{O}_3\text{S}$
D) $\text{C}_{13}\text{H}_{14}\text{NO}_2\text{S}$ E) $\text{C}_{12}\text{H}_{12}\text{N}_2\text{O}_2\text{S}$

9. Potassium iodate, KIO_3 , has applications as both source of dietary iodine in table salt and as protection against the accumulation of radioactive iodine in the human thyroid gland. The following reaction produces potassium iodate:



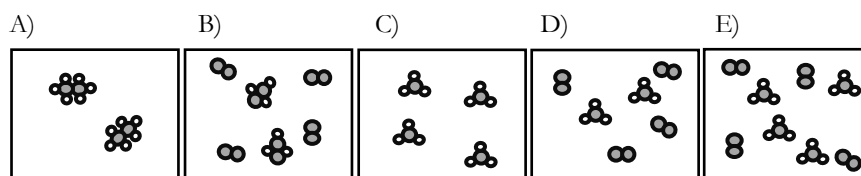
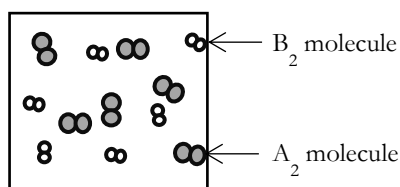
What is the theoretical yield of KIO_3 if the limiting reactant is 51.0 g I_2 ?

- A) 43.0 g B) 46.2 g C) 86.0 g D) 172 g E) 185 g

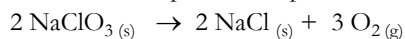
CCC 2015

1. To safely and efficiently prepare 1.0 L of a 1.0 mol L^{-1} solution of HCl from a 12.0 mol L^{-1} stock solution of HCl, what should a chemist add to a 1 L volumetric flask first?
- A) 500 mL of distilled water with a beaker
B) 120.0 mL of 12.0 mol L^{-1} HCl with a graduated cylinder
C) 83.3 mL of 12.0 mol L^{-1} HCl with a graduated cylinder
D) 12.0 mL of 12.0 mol L^{-1} HCl with a graduated cylinder
E) 10.0 mL of distilled water with a graduated cylinder

6. The top diagram represents the initial state of a mixture of diatomic gas A and diatomic gas B in a closed reaction flask. Which of the diagrams under the answer choices represents the contents of the flask if the reaction goes to completion? The balanced chemical equation is: $A_2 + 3 B_2 \rightarrow 2 AB_3$



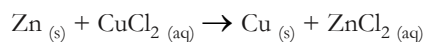
13. In the *emergency oxygen system* on commercial passenger aircraft, sodium chlorate undergoes thermal decomposition to produce oxygen gas:



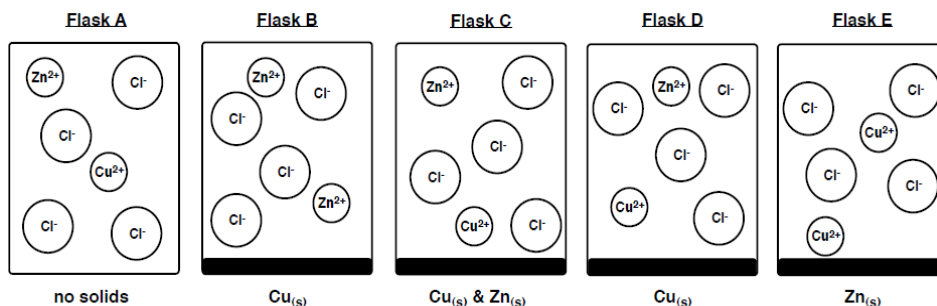
On average a human under stress consumes 38.0 L of O₂ through respiration every 15 minutes. Determine the *minimum* mass of sodium chlorate required to deliver this volume of O₂ (assume $P = 100 \text{ kPa}$ and $T = 273.15 \text{ K}$)

- A) 65.0 g B) 119 g C) 178 g D) 267 g E) 356 g

15. The chemical reaction that takes place when 1.30 g of pure zinc is mixed with 400 mL of a 0.100 mol L⁻¹ copper (II) chloride solution is :



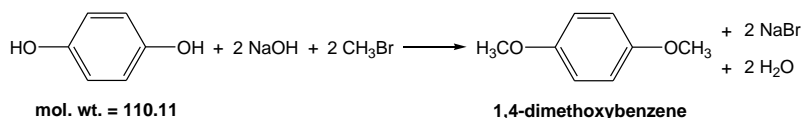
Which diagram best represents the system after the reaction has gone to completion?



17. One of the Twelve Principles of Green Chemistry is that “synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product”. One way to consider this is to calculate the *atom economy* (AE) of a chemical reaction where AE is defined as follows:

$$\text{atom economy} = \frac{\text{molecular mass of desired product}}{\text{molecular mass of all reactants}} \times 100\%$$

1,4-Dimethoxybenzene is an organic compound with an intensely sweet floral odour and used in the perfumery industry. It can be synthesized in the laboratory by the reaction shown below:

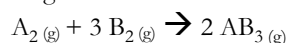


What is the percentage atom economy for this reaction?

- A) 46.1% B) 36.3% C) 56.4% D) 67.4% E) 20.6%
18. The reaction $2 A + B_2 \rightarrow 2 AB$ is first order in $[B_2]$ and zero order in $[A]$. The half-life for the overall reaction is 2 minutes. If 0.100 moles of A and 0.0300 moles of B_2 are dissolved in 100.0 mL of solvent, what will $[A]$ be, 6.00 minutes after the reaction begins?
- A) $0.00125 \text{ mol L}^{-1}$ B) 0.125 mol L^{-1} C) $0.00375 \text{ mol L}^{-1}$
 D) 0.738 mol L^{-1} E) 0.475 mol L^{-1}

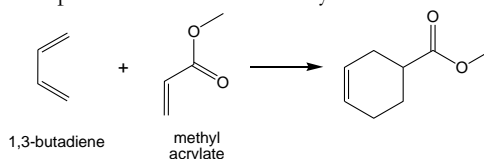
CCC 2014

3. The reaction for a homogeneous gas phase reaction of reactants “ A_2 ” and “ B_2 ” and product “ AB_3 ” is given as:



If equal volumes of reactants “ A_2 ” and “ B_2 ” are mixed together in a rigid container at 1.50×10^2 atm and a constant temperature of 25°C , what is the partial pressure in atmospheres (atm) of the gaseous product AB_3 ? Assume the reaction goes to completion.

- A) 37.5 B) 50.0 C) 75.0 D) 1.00×10^2 E) 1.50×10^2
6. One of the Twelve Principles of Green Chemistry is that “it is better to prevent waste, rather than clean it up”. Waste can be created during a chemical process from unreacted starting materials and from the formation of by-products. During the reaction below, 1.26 mol of 1,3-butadiene (formula C_4H_6) was combined with 2.31 mol of methyl acrylate (formula $C_4H_6O_2$) to form the product shown in 86.4% yield.



What is the mass of waste generated during this reaction?

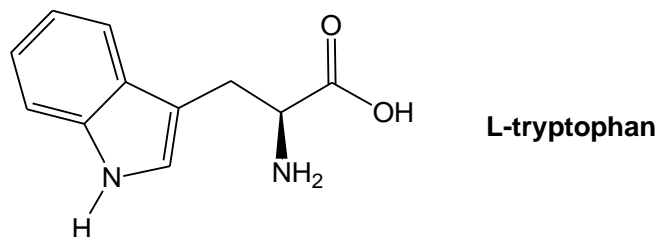
- A) 90.4 g B) 1.10×10^2 g C) 114 g D) 152 g E) 294 g



11. Sulfuric acid, nitrogen dioxide gas and water are produced when elemental sulfur (S) is immersed in nitric acid in a laboratory experiment. If 3.00 g of sulfur are mixed with 600.0 mL of 1.00 mol L^{-1} nitric acid, what volume of nitrogen dioxide will be formed at 0°C and 100 kPa?
- A) 2.10 L B) 2.23 L C) 8.40 L D) 12.7 L E) 13.4 L

Questions 15 and 16 relate to the following information

L-Tryptophan (structure below) is one of the essential amino acids in the human diet. It is a common medical myth that L-tryptophan consumed during a turkey dinner is responsible for the tiredness felt afterwards even though turkey does not contain an especially large proportion of L-tryptophan. Answer the following two questions about this compound.



16. What is the percentage by mass of oxygen found in L-tryptophan?
- A) 5.90 % B) 13.7 % C) 15.7 % D) 22.8 % E) 64.7 %

CCC 2013

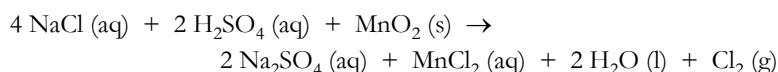
4. A volatile alkane ($\text{C}_x\text{H}_{2x+2}$) is analyzed by the Dumas method to determine its molar mass. A 0.01613 g sample of the compound is injected under vacuum into a 100.00 mL flask at 25.0°C . The pressure of the sample is 13.33 kPa. What is the molecular formula of the alkane?
- A. CH_4 B. C_2H_6 C. C_3H_8 D. C_4H_{10} E. C_5H_{12}
7. During a lab experiment, 0.250 g of copper metal is recovered, and is left overnight to ensure that it is totally dry. The following day, the copper product is greeny-blue in colour and has a mass of 0.490 g. Assuming only one copper product is produced from the original copper metal, that product is likely:
- A. CuO B. Cu_2O C. CuCO_3 D. Cu_2CO_3 E. Cu_3N_2



17. A forensic laboratory analyzed a white powder. Tests indicated that the powder is a known drug mixed with sodium chloride. An elemental analysis gave the following results: 60.58% C, 6.282% H, 4.158% N. Assume the white powder is only a mixture of the pure drug and NaCl. Which drug is in the white powder and what is the **percent by mass** content of sodium chloride in it?

- A. Cocaine (C₁₇H₂₁NO₄); contains 20% NaCl by mass
- B. Morphine (C₁₇H₁₉NO₃); contains 20% NaCl by mass
- C. Cocaine (C₁₇H₂₁NO₄); contains 10% NaCl by mass
- D. Morphine (C₁₇H₁₉NO₃); contains 10% NaCl by mass
- E. Cocaine (C₁₇H₂₁NO₄); contains 15% NaCl by mass

18. In 1774, Swedish chemist Carl Wilhelm Scheele produced molecular chlorine gas from the reaction between sodium chloride, sulfuric acid, and manganese(IV) oxide shown below:



To reproduce Scheele's experiment, 50.0 mL of 2.00 mol L⁻¹ NaCl is mixed with 25.0 mL of 6.00 mol L⁻¹ H₂SO₄, and 4.35 g of MnO₂. What volume of Cl₂ gas will be produced at 101.325 kPa of pressure and 25.0°C of temperature?

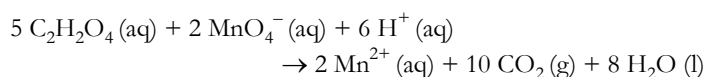
- A. 0.611 L Cl₂ (g)
- B. 1.22 L Cl₂ (g)
- C. 1.83 L Cl₂ (g)
- D. 2.44 L Cl₂ (g)
- E. 3.67 L Cl₂ (g)

CCC 2012

14. A mixed oxide has the formula X₇O₈. If element X exists as both X²⁺ and X³⁺ in the compound, what is the ratio of X²⁺/X³⁺?

- A. 0.438
- B. 0.875
- C. 1.14
- D. 2.29
- E. **2.50**

17. Oxalic acid, C₂H₂O₄, reacts with the permanganate ion according to the equation:

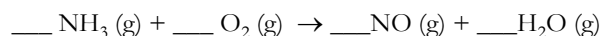


If 25.0 mL of 0.0150 mol L⁻¹ KMnO₄ reacts with 25.0 mL of 0.0208 mol L⁻¹ C₂H₂O₄, how many moles of carbon dioxide gas will be produced?

- A. 3.75 x 10⁻⁴ mol
- B. 5.20 x 10⁻⁴ mol
- C. 8.95 x 10⁻⁴ mol
- D. **1.04 x 10⁻³ mol**
- E. 1.88 x 10⁻³ mol



4. Nitric oxide is made from the oxidation of ammonia at high temperatures and in the presence of a platinum catalyst according to the **unbalanced** equation:

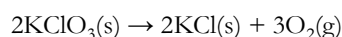


Assuming the reactants and the products are at the same temperature and pressure and excess ammonia reacts with 13.96 L of oxygen gas to produce 8.96 L of nitric oxide, what is the percent yield of the reaction?

- A. 19.8 % B. 51.3 % C. 64.2 % **D. 80.2 %** E. 95.4 %

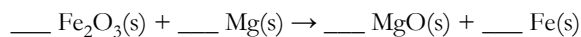
CCC 201%

4. If the yield for the following reaction is 65.0% by mass, what mass of KClO_3 is needed to produce 32.0 g of O_2 ?



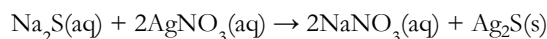
- A. 53.1 g B. 81.7 g C. 62.8 g D. 283 g E. 126 g

8. The following thermite reaction is used for welding when space and weight limit the use of conventional welding equipment. Balance the chemical equation given below and determine the mass of Mg needed to produce 15.0 kg of Fe:



- A. 9.80 kg B. 5.20 kg C. 6.50 kg D. 4.40 kg E. 3.40 kg

9. For the following reaction, what volume of aqueous $0.260 \text{ mol L}^{-1} \text{Na}_2\text{S}$ is needed to react with 25.0 mL of $0.315 \text{ mol L}^{-1} \text{AgNO}_3$?



- A. 25.0 mL B. 30.3 mL C. 20.3 mL D. 60.6 mL E. 15.1 mL

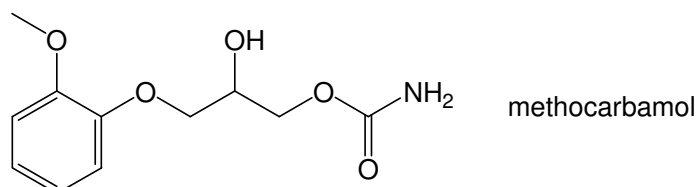
21. For a saturated solution of $\text{Ca}(\text{OH})_2$ placed in a drying oven the following data are collected:

Volume of saturated $\text{Ca}(\text{OH})_2$ (mL)	25.00
Mass of beaker (g)	20.960
Mass of beaker + dry solid (g)	20.981

What is the molar solubility of $\text{Ca}(\text{OH})_2$ per litre of water? Assume the dry solid is $\text{Ca}(\text{OH})_2(\text{s})$

- A. 0.84 mol L^{-1} B. $2.8 \times 10^{-4} \text{ mol L}^{-1}$ C. $5.5 \times 10^{-6} \text{ mol L}^{-1}$
D. 0.027 mol L^{-1} E. 0.011 mol L^{-1}

16. The active ingredients in Robaxacet[®], an over-the-counter painkiller, are methocarbamol (structure below, molar mass = 241.2 g mol⁻¹) and acetaminophen (formula C₈H₉NO₂, molar mass = 151.1 g mol⁻¹). Methocarbamol is a relaxant used to treat muscular spasms.

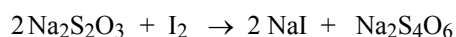


Calculate the total percentage of oxygen present by mass in the active ingredients of a Robaxacet[®] tablet containing 400 mg of methocarbamol and 500 mg of acetaminophen.

- A. 21.2% B. 24.3% C. 26.5% D. 28.5% E. 33.2%
17. Copper can be electroplated onto a cathode of another metal from a solution of copper (II) nitrate. If the current used for the electrolysis is 1.62 C s⁻¹, how much copper can be deposited on the cathode in one hour?
- A. 1.92 g B. 3.79 g C. 3.84 g D. 5.67 g E. 7.68 g

CCC 2010

4. When analysing water, each mole of dissolved oxygen (O₂) liberates two moles of iodine (I₂) through a series of complex redox reactions involving manganese and iodine. The amount of dissolved iodine is then accurately determined by titration with standard sodium thiosulfate solution. The balanced equation representing the titration is:



A 25.00-mL water sample required 18.64 mL of a 0.00113 mol L⁻¹ sodium thiosulfate solution to titrate the amount of iodine present after the original treatment. What is the concentration of dissolved oxygen in this sample (in mg O₂ per litre of water)?

- A. 0.211 mg O₂/L B. 3.37 mg O₂/L C. 6.74 mg O₂/L
 D. 13.48 mg O₂/L E. 18.64 mg O₂/L

7. A student reported that in the synthesis of an iodide of tin, 0.500 g of tin and 2.00 g of iodine were completely consumed in the reaction. From these data, you can conclude that the formula of the tin iodide is:

- A. SnI₂, with an experimental error of more than 10%
 B. SnI₂, with an experimental error of less than 10%
 C. SnI₄, with no appreciable experimental error
 D. SnI₄, with an experimental error of more than 10%
 E. SnI₄, with an experimental error of less than 10%



9. Aluminium reacts with oxygen to produce aluminium oxide. If 6.00 g of aluminium is reacted with 6.00 g of oxygen gas, what is the maximum mass of aluminium oxide that can be produced?

- A. 8.25 g Al_2O_3 B. 9.40 g Al_2O_3 C. 11.3 g Al_2O_3
D. 12.7 g Al_2O_3 E. 19.2 g Al_2O_3

10. A 2.0 cm length of magnesium ribbon was added to 100 mL of 2.0 mol L^{-1} hydrochloric acid. All the magnesium reacted and the temperature of the acid increased by 20°C .

What volume of 2.0 mol L^{-1} hydrochloric acid would produce a temperature rise of 10°C with a 1 cm length of magnesium ribbon?

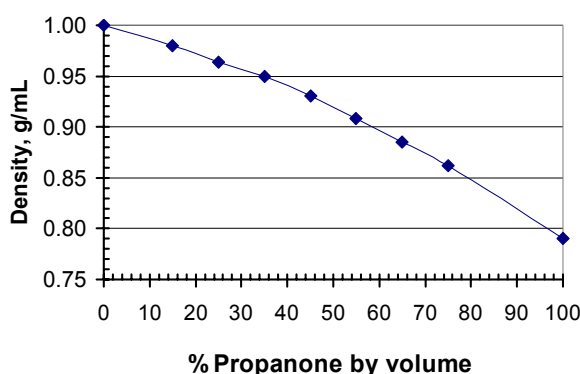
- A. 20 mL B. 25 mL C. 50 mL D. 100 mL E. 200 mL

11. A sample of baking soda of total mass 0.364 g is composed of sodium hydrogen carbonate, NaHCO_3 , mixed with a non-volatile impurity. When heated, the sodium hydrogen carbonate decomposes to sodium carbonate, Na_2CO_3 , and there is a loss in mass of 0.112 g. The purity of the NaHCO_3 mixture was:

- A. 30.8% B. 50.0% C. 69.2% D. 83.3% E. 90.3%

12. In an experiment to determine the percentage of water in a mixture of water and propanone (acetone), a 9.95-mL sample of a liquid mixture of propanone and water was weighed:

Experimental data: Mass of flask and sample = 103.639 g
Mass of flask alone = 94.604 g

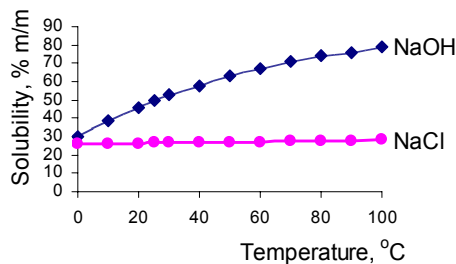


From the experimental data and the calibration graph shown above, what was the percentage of water by volume in the mixture?

- A. 32% B. 42% C. 58% D. 68% E. 75%



12. During the commercial electrolysis of brine by the membrane process, a concentrated solution containing approximately equal masses of sodium chloride and sodium hydroxide is partly evaporated at 100°C to give a mixture containing a solid and a solution. Using the solubility curves given below, determine which one of the statements about the mixture is correct:



- A. The solid contains mainly NaCl
- B. The solid contains mainly NaOH
- C. The solid contains equal masses of NaCl and NaOH
- D. The solution contains equal masses of NaCl and NaOH
- E. The solid and the solution each contain equal masses of NaCl and NaOH

13. Cryolite, Na_3AlF_6 , is a mineral used in the Hall-Héroult process for producing aluminum. Cryolite can be synthesized by the following reaction:



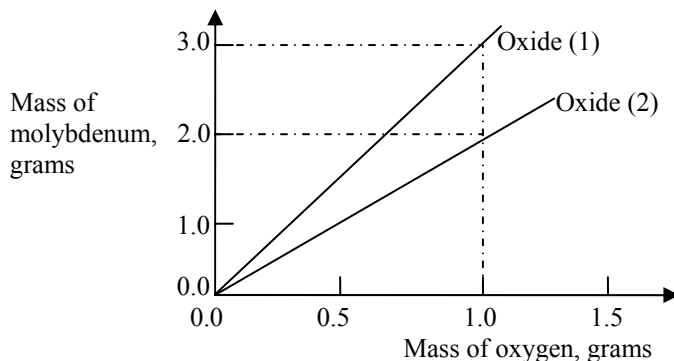
How many kilograms of cryolite are produced if the reaction has a 94.3% yield and a limiting reagent of 27.8 kilograms of HF?

- A. 15.0
- B. 15.9
- C. 45.9
- D. 48.6
- E. 275

23. Isoprene is an important hydrocarbon, containing two alkene functional groups, that is used to produce a synthetic version of natural rubber. When isoprene was treated with an excess of molecular bromine in dichloromethane solvent, compound **Q** was formed. Elemental analysis of **Q** showed it to be composed of 2.08% hydrogen and 82.43% bromine. What is the percentage of carbon present in isoprene?

- A. 15.49%
- B. 30.98%
- C. 85.63%
- D. 88.16%
- E. 90.12%

12. A group of researchers did an experiment to determine the mass ratio of molybdenum to oxygen in two different oxides. They combined their results to give the graph shown below:



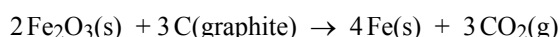
From these results it can be deduced that the formulae of the two metal oxides are:

	A	B	C	D	E
Oxide (1)	MoO	Mo ₂ O	o ₃ O	oO ₂	MoO ₃
Oxide (2)	Mo ₂ O ₃	Mo ₃ O	o ₂ O	oO ₃	MoO ₂

13. Flutamide (Eulexin[®]) is an important organic compound containing three fluorine atoms in each molecule. It is used in the treatment of prostate cancer. An analytical chemist extracted flutamide from a commercial tablet weighing 203.21 mg leaving a residue (containing non-medicinal ingredients) that weighed 128.23 mg. Elemental analysis of the extracted flutamide revealed the presence of 15.47 mg of fluorine. What is the molar mass (in g mol⁻¹) of flutamide?

A. 232.8 B. 254.5 C. 276.2 D. 286.9 E. 303.1

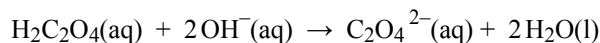
14. An example of a highly exothermic “thermite” reaction is used in the production of iron by the blast furnace process. The equation for this reaction is:



What is the maximum mass of iron metal can be obtained from 1235 kg of iron(III) oxide and 154.0 kg of graphite?

A. 477.5 kg B. 863.8 kg C. 714.8 kg
 D. 953.1 kg E. 955.7 kg

15. Oxalic acid (ethanedioic acid, H₂C₂O₄) has many uses in metal cleaning, textile dyeing and photography. Suppose you dissolve a 1.034-g sample of *impure* oxalic acid in some water, add an acid-base indicator, and titrate with NaOH (0.485 mol L⁻¹). The sample requires 34.47 mL of the NaOH solution to reach the equivalence point. The equation for the titration reaction is:



What is the **mass** of oxalic acid and what is its **mass percent** in the sample?

A. 0.547 g, 52.9% B. 0.654 g, 63.2% C. 0.729 g, 70.5%
 D. 0.752 g, 72.8% E. 0.856 g, 82.8%



19. The table below gives the solubilities of sodium nitrate and lithium chloride in 100 g of water at 20°C and 60°C.

Solubility in 100 g of water	20°C	60°C
Sodium nitrate	87.5 g	125 g
Lithium chloride	78.0 g	103 g

A 40.0-g sample of a mixture that is 50.0% by mass in each of sodium nitrate and lithium chloride is stirred in 20.0 g of water at 60°C until all of it dissolves. When the solution is cooled down to 20°C, white crystals appear and the latter are carefully recovered by filtration. Which one of the following gives the correct mass of recovered solid and the percent by mass of lithium chloride in it?

- A. 6.9 g of solid containing 36% LiCl
- B. 6.9 g of solid containing 64% LiCl
- C. 20.0 g of solid containing 22.0% LiCl
- D. 33.1 g of solid containing 63.8% LiCl
- E. 33.1 g of solid containing 47.1% LiCl

CCC 2007