

The Advanced Placement Examination in Chemistry

Part I – Multiple Choice Questions
Part II - Free Response Questions
Selected Questions from 1970 to 2010

StoichiometryPart I

1984

2. Which of the following forms a compound having the formula KXO_4 ?
- (A) F
(B) S
(C) Mg
(D) Ar
(E) Mn
32. The net ionic equation for the reaction between silver carbonate and hydrochloric acid is
- (A) $Ag_2CO_3(s) + 2 H^+ + 2 Cl^- \rightarrow 2 AgCl(s) + H_2O + CO_2(g)$
(B) $2 Ag^+ + CO_3^{2-} + 2 H^+ + 2 Cl^- \rightarrow 2 AgCl(s) + H_2O + CO_2(g)$
(C) $CO_3^{2-} + 2 H^+ \rightarrow H_2O + CO_2(g)$
(D) $Ag^+ + Cl^- \rightarrow AgCl(s)$
(E) $Ag_2CO_3(s) + 2 H^+ \rightarrow 2 Ag^+ + H_2CO_3$
44. What number of moles of O_2 is needed to produce 14.2 grams of P_4O_{10} from P? (Molecular weight $P_4O_{10} = 284$)
- (A) 0.0500 mole
(B) 0.0625 mole
(C) 0.125 mole
(D) 0.250 mole
(E) 0.500 mole
45. The alkenes are compounds of carbon and hydrogen with the general formula C_nH_{2n} . If 0.561 gram of any alkene is burned in excess oxygen, what number of moles of H_2O is formed?
- (A) 0.0400 mole
(B) 0.0600 mole
(C) 0.0800 mole
(D) 0.400 mole
(E) 0.800 mole
52. $3 Ag(s) + 4 HNO_3 \rightarrow 3 AgNO_3 + NO(g) + 2 H_2O$
The reaction of silver metal and dilute nitric acid proceeds according to the equation above. If 0.10 mole of powdered silver is added to 10. milliliters of 6.0-molar nitric acid, the number of moles of NO gas that can be formed is
- (A) 0.015 mole
(B) 0.020 mole
(C) 0.030 mole
(D) 0.045 mole
(E) 0.090 mole

73. A 27.0-gram sample of an unknown hydrocarbon was burned in excess oxygen to form 88.0 grams of carbon dioxide and 27.0 grams of water. What is a possible molecular formula of the hydrocarbon?
- (A) CH_4
 - (B) C_2H_2
 - (C) C_4H_3
 - (D) C_4H_6
 - (E) C_4H_{10}
- 1989
15. The weight of H_2SO_4 (molecular weight 98.1) in 50.0 milliliters of a 6.00-molar solution is
- (A) 3.10 grams
 - (B) 12.0 grams
 - (C) 29.4 grams
 - (D) 294 grams
 - (E) 300. grams
23. How many grams of calcium nitrate, $\text{Ca}(\text{NO}_3)_2$, contains 24 grams of oxygen atoms?
- (A) 164 grams
 - (B) 96 grams
 - (C) 62 grams
 - (D) 50. grams
 - (E) 41 grams
24. The mass of element Q found in 1.00 mole of each of four different compounds is 38.0 grams, 57.0 grams, 76.0 grams, and 114 grams, respectively. A possible atomic weight of Q is
- (A) 12.7
 - (B) 19.0
 - (C) 27.5
 - (D) 38.0
 - (E) 57.0
25. The simplest formula for an oxide of nitrogen that is 36.8 percent nitrogen by weight is
- (A) N_2O
 - (B) NO
 - (C) NO_2
 - (D) N_2O_3
 - (E) N_2O_5
26. How many milliliters of 11.6-molar HCl must be diluted to obtain 1.0 liter of 3.0-molar HCl ?
- (A) 3.9 mL
 - (B) 35 mL
 - (C) 260 mL
 - (D) 1,000 mL
 - (E) 3,900 mL
39. When a hydrate of Na_2CO_3 is heated until all the water is removed, it loses 54.3 percent of its mass. The formula of the hydrate is
- (A) $\text{Na}_2\text{CO}_3 \cdot 10 \text{H}_2\text{O}$
 - (B) $\text{Na}_2\text{CO}_3 \cdot 7 \text{H}_2\text{O}$
 - (C) $\text{Na}_2\text{CO}_3 \cdot 5 \text{H}_2\text{O}$
 - (D) $\text{Na}_2\text{CO}_3 \cdot 3 \text{H}_2\text{O}$

(E) $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$

44. The metal calcium reacts with molecular hydrogen to form a compound. All of the following statements concerning this compound are true EXCEPT:
- (A) Its formula is CaH_2 .
 - (B) It is ionic.
 - (C) It is solid at room temperature.
 - (D) When added to water, it reacts to produce H_2 gas.
 - (E) When added to water, it forms an acidic solution.
72. How many moles of solid $\text{Ba}(\text{NO}_3)_2$ should be added to 300. milliliters of 0.20-molar $\text{Fe}(\text{NO}_3)_3$ to increase the concentration of the NO_3^- ion to 1.0-molar? (Assume that the volume of the solution remains constant.)
- (A) 0.060 mole
 - (B) 0.12 mole
 - (C) 0.24 mole
 - (D) 0.30 mole
 - (E) 0.40 mole

1994

19. In which of the following compounds is the mass ratio of chromium to oxygen closest to 1.62 to 1.00?
- (A) CrO_3
 - (B) CrO_2
 - (C) CrO
 - (D) Cr_2O
 - (E) Cr_2O_3
53. If 87 grams of K_2SO_4 (molar mass 174 grams) is dissolved in enough water to make 250 milliliters of solution, what are the concentrations of the potassium and the sulfate ions?
- | $[\text{K}^+]$ | $[\text{SO}_4^{2-}]$ |
|----------------|----------------------|
| (A) 0.020 M | 0.020 M |
| (B) 1.0 M | 2.0 M |
| (C) 2.0 M | 1.0 M |
| (D) 2.0 M | 2.0 M |
| (E) 4.0 M | 2.0 M |
55. What volume of 0.150-molar HCl is required to neutralize 25.0 milliliters of 0.120-molar $\text{Ba}(\text{OH})_2$?
- (A) 20.0 mL
 - (B) 30.0 mL
 - (C) 40.0 mL
 - (D) 60.0 mL
 - (E) 80.0 mL
70. To determine the molar mass of a solid monoprotic acid, a student titrated a weighed sample of the acid with standardized aqueous NaOH . Which of the following could explain why the student obtained a molar mass that was too large?
- I. Failure to rinse all acid from the weighing paper into the titration vessel
 - II. Addition of more water than was needed to dissolve the acid
 - III. Addition of some base beyond the equivalence point
- (A) I only
 - (B) III only

- (C) I and II only
- (D) II and III only
- (E) I, II, and III

1999

18. Which of the following elements reacts with water to form a strong base?

- (A) Lithium
- (B) Nickel
- (C) Bromine
- (D) Uranium
- (E) Fluorine

20. What mass of Au is produced when 0.0500 mol of Au_2S_3 is reduced completely with excess H_2 ?

- (A) 9.85 g
- (B) 19.7 g
- (C) 24.5 g
- (D) 39.4 g
- (E) 48.9 g



26. When the equation above is balanced and all coefficients are reduced to their lowest whole-number terms, the coefficient for $\text{O}_2(g)$ is

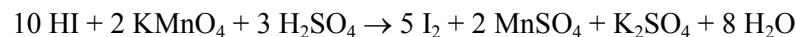
- (A) 6
- (B) 7
- (C) 12
- (D) 14
- (E) 28

33. A 1.0 L sample of an aqueous solution contains 0.10 mol of NaCl and 0.10 mol of CaCl_2 . What is the minimum number of moles of AgNO_3 that must be added to the solution in order to precipitate all of the Cl^- as $\text{AgCl}(s)$? (Assume that AgCl is insoluble.)

- (A) 0.10 mol
- (B) 0.20 mol
- (C) 0.30 mol
- (D) 0.40 mol
- (E) 0.60 mol

47. When hafnium metal is heated in an atmosphere of chlorine gas, the product of the reaction is found to contain 62.2 percent Hf by mass and 37.4 percent Cl by mass. What is the empirical formula for this compound?

- (A) HfCl
- (B) HfCl_2
- (C) HfCl_3
- (D) HfCl_4
- (E) Hf_2Cl_3



55. According to the balanced equation above, how many moles of HI would be necessary to produce 2.5 mol of I_2 , starting with 4.0 mol of KMnO_4 and 3.0 mol of H_2SO_4 ?

- (A) 20.

- (B) 10.
(C) 8.0
(D) 5.0
(E) 2.5
59. A 40.0 mL sample of 0.25 *M* KOH is added to 60.0 mL of 0.15 *M* Ba(OH)₂. What is the molar concentration of OH⁻(aq) in the resulting solution? (Assume that the volumes are additive.)
(A) 0.10 *M*
(B) 0.19 *M*
(C) 0.28 *M*
(D) 0.40 *M*
(E) 0.55 *M*
69. What is the final concentration of barium ions, [Ba²⁺], in solution when 100. mL of 0.10 *M* BaCl₂(aq) is mixed with 100. mL of 0.050 *M* H₂SO₄(aq)?
(A) 0.00 *M*
(B) 0.012 *M*
(C) 0.025 *M*
(D) 0.075 *M*
(E) 0.10 *M*
72. After completing an experiment to determine gravimetrically the percentage of water in a hydrate, a student reported a value of 38 percent. The correct value for the percentage of water in the hydrate is 51 percent. Which of the following is the most likely explanation for this difference?
(A) Strong initial heating caused some of the hydrate sample to spatter out of the crucible.
(B) The dehydrated sample absorbed moisture after heating.
(C) The amount of the hydrate sample used was too small.
(D) The crucible was not heated to constant mass before use.
(E) Excess heating caused the dehydrated sample to decompose.
73. The volume of distilled water that should be added to 10.0 mL of 6.00 *M* HCl(aq) in order to prepare a 0.500 *M* HCl(aq) solution is approximately
(A) 50.0 mL
(B) 60.0 mL
(C) 100. mL
(D) 110. mL
(E) 120. mL

2002

Questions 6-7 refer to the following solid compounds.

- (A) PbSO₄
(B) CuO
(C) KMnO₄
(D) KCl
(E) FeCl₃
6. Is purple in aqueous solution
7. Is white and very soluble in water
24. A compound contains 1.10 mol of K, 0.55 mol of Te, and 1.65 mol of O. What is the simplest formula of this compound?
(A) KTeO
(B) KTe₂O

- (C) K_2TeO_3
- (D) K_2TeO_6
- (E) K_4TeO_6

26. Approximately what mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (250 g mol^{-1}) is required to prepare 250 mL of 0.10 M copper(II) sulfate solution?

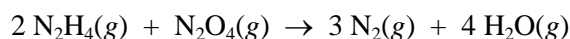
- (A) 4.0 g
- (B) 6.2 g
- (C) 34 g
- (D) 85 g
- (E) 140 g

32. Which of the following oxides is a gas at 25°C and 1 atm ?

- (A) Rb_2O
- (B) N_2O
- (C) Na_2O_2
- (D) SiO_2
- (E) La_2O_3

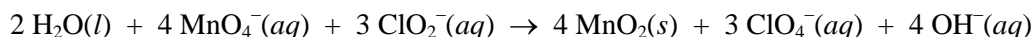
52. Propane gas, C_3H_8 , burns in excess oxygen gas. When the equation for the reaction is correctly balanced and all coefficients are reduced to their lowest whole-number terms, the coefficient for O_2 is

- (A) 4
- (B) 5
- (C) 7
- (D) 10
- (E) 22



58. When 8.0 g of N_2H_4 (32 g mol^{-1}) and 92 g of N_2O_4 (92 g mol^{-1}) are mixed together and react according to the equation above, what is the maximum mass of H_2O that can be produced?

- (A) 9.0 g
- (B) 18 g
- (C) 36 g
- (D) 72 g
- (E) 144 g



60. According to the balanced equation above, how many moles of $\text{ClO}_2^-(\text{aq})$ are needed to react completely with 20. mL of 0.20 M KMnO_4 solution?

- (A) 0.0030 mol
- (B) 0.0053 mol
- (C) 0.0075 mol
- (D) 0.013 mol
- (E) 0.030 mol

69. If 200. mL of 0.60 M $\text{MgCl}_2(\text{aq})$ is added to 400. mL of distilled water, what is the concentration of $\text{Mg}^{2+}(\text{aq})$ in the resulting solution? (Assume volumes are additive.)

- (A) 0.20 M
- (B) 0.30 M
- (C) 0.40 M

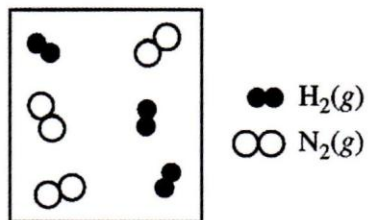
- (D) 0.60 M
- (E) 1.2 M

2008

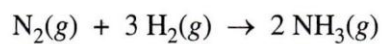
31. A compound contains 30. percent sulfur and 70. percent fluorine by mass. The empirical formula of the compound is
- (A) SF
 - (B) SF₂
 - (C) SF₄
 - (D) SF₆
 - (E) S₂F
33. If 0.40 mol of H₂ and 0.15 mol of O₂ were to react as completely as possible to produce H₂O, what mass of reactant would remain?
- (A) 0.20 g of H₂
 - (B) 0.40 g of H₂
 - (C) 3.2 g of O₂
 - (D) 4.0 g of O₂
 - (E) 4.4 g of O₂



34. When the equation above is balanced and all coefficients are reduced to lowest whole-number terms, what is the coefficient for H₃PO₄(l) ?
- (A) 1
 - (B) 2
 - (C) 3
 - (D) 4
 - (E) 5
36. How many carbon atoms are contained in 2.8 g of C₂H₄ ?
- (A) 1.2×10^{23}
 - (B) 3.0×10^{23}
 - (C) 6.0×10^{23}
 - (D) 1.2×10^{24}
 - (E) 6.0×10^{24}



41. The diagram above represents $\text{H}_2(g)$ and $\text{N}_2(g)$ in a closed container. Which of the following diagrams would represent the results if the reaction shown below were to proceed as far as possible?



(A)

(B)

(C)

(D)

(E)

72. When mixed, each of the following pairs of reactants gives visible evidence of a chemical reaction EXCEPT
- (A) $\text{Na}_2\text{CO}_3(s) + \text{HCl}(aq)$
 (B) $\text{Zn}(s) + \text{HCl}(aq)$
 (C) $\text{Ba}(\text{NO}_3)_2(aq) + \text{Na}_2\text{SO}_4(aq)$
 (D) $\text{FeCl}_3(aq) + \text{KOH}(aq)$
 (E) $\text{NH}_4\text{Cl}(aq) + \text{HCl}(aq)$

Part II

1982

Water is added to 4.267 grams of UF_6 . The only products are 3.730 grams of a solid containing only uranium, oxygen and fluorine and 0.970 gram of a gas. The gas is 95.0% fluorine, and the remainder is hydrogen.

- From these data, determine the empirical formula of the gas.
- What fraction of the fluorine in the original compound is in the solid and what fraction is in the gas after the reaction?
- What is the formula of the solid product?
- Write a balanced equation for the reaction between UF_6 and H_2O . Assume that the empirical formula of the gas is the true formula.

1986

Three volatile compounds X, Y, and Z each contain element Q. The percent by weight of element Q in each compound was determined. Some of the data obtained are given below.

<u>Compound</u>	<u>Percent by weight of Element Q</u>	<u>Molecular Weight</u>
X	64.8%	?
Y	73.0%	104.
Z	59.3%	64.0

- The vapor density of compound X at 27°C and 750. mm Hg was determined to be 3.53 grams per liter. Calculate the molecular weight of compound X.
- Determine the mass of element Q contained in 1.00 mole of each of the three compounds.
- Calculate the most probable value of the atomic weight of element Q.
- Compound Z contains carbon, hydrogen, and element Q. When 1.00 gram of compound Z is oxidized and all of the carbon and hydrogen are converted to oxides, 1.37 grams of CO_2 and 0.281 gram of water are produced. Determine the most probable molecular formula of compound Z.

1989

Consider three unlabeled bottles, each contain small pieces of one of the following metals.

- Magnesium
- Sodium
- Silver

The following reagents are used for identifying the metals.

- Pure water
- A solution of 1.0 molar HCl
- A solution of concentrated HNO_3

- Which metal can be easily identified because it is much softer than the other two? Describe a chemical test that distinguishes this metal from the other two, using only one of the reagents above. Write a balanced chemical equation for the reaction that occurs.
- One of the other two metals reacts readily with the HCl solution. Identify the metal and write the balanced chemical equation for the reaction that occurs when this metal is added to the HCl solution. Use the table of standard reduction potentials (attached) to account for the fact that this metal reacts with HCl while the other does not.
- The one remaining metal reacts with the concentrated HNO_3 solution. Write a balanced chemical equation for the reaction that occurs.
- The solution obtained in (c) is diluted and a few drops of 1 M HCl is added. Describe what would be observed. Write a balanced chemical equation for the reaction that occurs.

1991

The molecular formula of a hydrocarbon is to be determined by analyzing its combustion products and investigating its colligative properties.

- The hydrocarbon burns completely, producing 7.2 grams of water and 7.2 liters of CO_2 at standard conditions. What is the empirical formula of the hydrocarbon?
- Calculate the mass in grams of O_2 required for the complete combustion of the sample of the hydrocarbon described in (a).

1995

A sample of dolomitic limestone containing only CaCO_3 and MgCO_3 was analyzed.

- When a 0.2800 gram sample of this limestone was decomposed by heating, 75.0 milliliters of CO_2 at 750 mm Hg and 20°C were evolved. How many grams of CO_2 were produced?
- Write equations for the decomposition of both carbonates described above.
- It was also determined that the initial sample contained 0.0448 gram of calcium. What percent of the limestone by mass was CaCO_3 ?
- How many grams of the magnesium-containing product were present in the sample in (a) after it had been heated?

2000

Answer the following questions about $\text{BeC}_2\text{O}_4(s)$ and its hydrate.

- Calculate the mass percent of carbon in the hydrated form of the solid that has the formula $\text{BeC}_2\text{O}_4 \cdot 3\text{H}_2\text{O}$.
- When heated to $220.^\circ\text{C}$, $\text{BeC}_2\text{O}_4 \cdot 3\text{H}_2\text{O}(s)$ dehydrates completely as represented below.

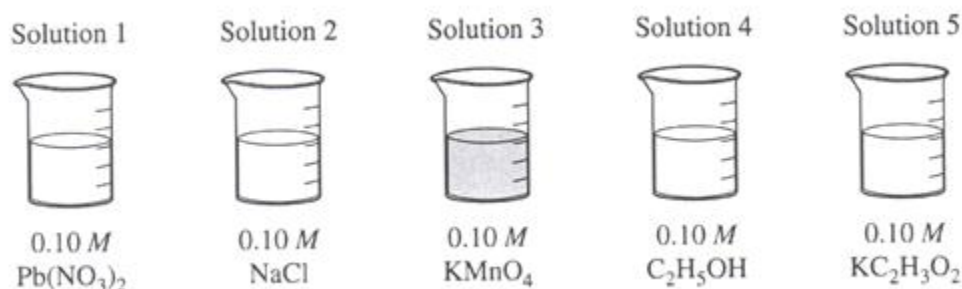
$$\text{BeC}_2\text{O}_4 \cdot 3\text{H}_2\text{O}(s) \rightarrow \text{BeC}_2\text{O}_4(s) + 3 \text{H}_2\text{O}(g)$$
 If 3.21 g of $\text{BeC}_2\text{O}_4 \cdot 3\text{H}_2\text{O}(s)$ is heated to $220.^\circ\text{C}$ calculate
 - the mass of $\text{BeC}_2\text{O}_4(s)$ formed, and,
 - the volume of the $\text{H}_2\text{O}(g)$ released, measured at $220.^\circ\text{C}$ and 735 mm Hg.

2001 (1)

Answer the following questions about acetylsalicylic acid, the active ingredient in aspirin.

- The amount of acetylsalicylic acid in a single aspirin tablet is 325 mg, yet the tablet has a mass of 2.00 g. Calculate the mass percent of acetylsalicylic acid in the tablet.
- The elements contained in acetylsalicylic acid are hydrogen, carbon, and oxygen. The combustion of 3.000 g of the pure compound yields 1.200 g of water and 3.72 L of dry carbon dioxide, measured at 750. mm Hg and 25°C . Calculate the mass, in g, of each element in the 3.000 g sample.

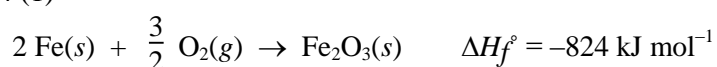
2001 (2)



Answer the question below that relate to the five aqueous solutions at 25°C shown above.

Identify a pair of the solutions that would produce a precipitate when mixed together. Write the formula of the precipitate.

2004 (1)



Iron reacts with oxygen to produce iron(III) oxide as represented above. A 75.0 g sample of Fe(s) is mixed with 11.5 L of O₂(g) at 2.66 atm and 298 K.

- Calculate the number of moles of each of the following before the reaction occurs.
 - Fe(s)
 - O₂(g)
- Identify the limiting reactant when the mixture is heated to produce Fe₂O₃. Support your answer with calculations.

2004 (2)

Answer the following question about carbon monoxide, CO(g), and carbon dioxide, CO₂(g). Assume that both gases exhibit ideal behavior.

One of the two gases dissolves readily in water to form a solution with a pH below 7. Identify the gas and account for this observation by writing a chemical reaction.

2005

Answer the following question about a pure compound that contains only carbon, hydrogen, and oxygen.

A 0.7549 g sample of the compound burns in O₂(g) to produce 1.9061 g of CO₂(g) and 0.3370 g of H₂O(g).

- Calculate the individual masses of C, H, and O in the 0.7549 g sample.
- Determine the empirical formula for the compound.

2008

Answer the following questions relating to gravimetric analysis.

In the first of two experiments, a student is assigned to task of determining the number of moles of water in one mole of MgCl₂ · n H₂O. The student collects the data shown in the following table.

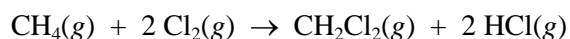
Mass of empty container	22.347 g
Initial mass of sample and container	25.825 g
Mass of sample and container after first heating	23.982 g
Mass of sample and container after second heating	23.976 g
Mass of sample and container after third heating	23.977 g

- (a) Explain why the student can correctly conclude that the hydrate was heated a sufficient number of times in the experiment.
- (b) Use the data above to
 - (i) calculate the total number of moles of water lost when the sample was heated, and
 - (ii) determine the formula of the hydrated compound.
- (c) A different student heats the hydrate in an uncovered crucible, and some of the solid spatters out of the crucible. This spattering will have what effect on the calculated mass of the water lost by the hydrate? Justify your answer.

In the second experiment, a student is given 2.94 g of a mixture containing anhydrous MgCl_2 and KNO_3 . To determine the percentage by mass of MgCl_2 in the mixture, the student uses excess $\text{AgNO}_3(aq)$ to precipitate the chloride ion as $\text{AgCl}(s)$.

- (d) Starting with a 2.94 g sample of the mixture dissolved in water, briefly describe the steps necessary to quantitatively determine the mass of the AgCl precipitate.
- (e) The student determines the mass of the AgCl precipitate to be 5.48 g. On the basis of this information, calculate each of the following.
 - (i) The number of moles of MgCl_2 in the original mixture.
 - (ii) The percent by mass of MgCl_2 in the original mixture.

2009



Methane gas reacts with chlorine gas to form dichloromethane and hydrogen chloride, as represented by the equation above. A 25.0 g sample of methane gas is placed in a reaction vessel containing 2.58 mol of $\text{Cl}_2(g)$.

- (a) Identify the limiting reactant when the methane and chlorine gases are combined. Justify your answer with a calculation.
- (b) Calculate the total number of moles of $\text{CH}_2\text{Cl}_2(g)$ in the container after the limiting reactant has been totally consumed.