AP Chemistry – Chapters 1 and 2

AP Study Guide for Chapter 1

Students should be able to...

- Define chemistry
- Describe the difference between mass and weight
- Describe the difference between chemical and physical change
- Describe the difference between accuracy and precision
- Describe the five states of matter, and give an example of each
- List the SI base units for length, mass, volume, time, and temperature
- List and convert using the SI prefixes: kilo-, centi-, milli-, micro-, and nano-
- Convert temperatures from and to degrees Celsius to Kelvin (add 273.15), or degrees Farenheit)
- Convert mass, length, and volume between the SI and English systems (2.54 cm = 1 inch, 454 g = 1 pound, .946 L = 1 quart)
- Calculate the density of a solid (mass / volume)
- Express numbers in scientific notation
- Express scientific notation in decimal form
- Compute numbers in scientific notation using a calculator
- Be familiar with the following terms: atom, element, molecule, compound, mixture, homogeneous, heterogeneous, extensive, intensive
- Decide if a digit in a number is "significant"
- Round answers to arithmetic problems to reflect the precision of the number

AP Study Guide for Chapter 2

Students should be able to...

- Describe Dalton's atomic theory.
- Count protons, neutrons, and electrons in an isotope.
- Know properties of protons, neutrons, and electrons including: symbol, mass number, location, and relative charge.
- Describe the Rutherford experiment, and how it proved the existence of the nucleus.
- Describe the Millikan experiment.
- Write isotopes in hyphen notation and nuclear symbol notation.
- Define: atomic number, mass number, average atomic mass, group/family, period/series, ionic bond, covalent bond
- Know names of Group IA, IIA, VIIA, and noble gases; actinides and lanthanides
- Describe the formation of ions from atoms
- Know common polyatomic ions
- Find the oxidation number (Roman numeral) of an element, either free or in a compound
- Write the name from the formula and write the formula from the name of these types of inorganics: binary ionic compounds, binary compounds composed of 2 nonmetals, ternary compounds, binary acids, and ternary acids

Old AP test questions – Copyright College Board

33. Which of the following conclusions can be drawn from J. J. Thomson's cathode ray experiments?
    a. Atoms contain electrons.
    b. Practically all the mass of an atom is contained in its nucleus.
    c. Atoms contain protons, neutrons, and electrons.
    d. Atoms have a positively charged nucleus surrounded by an electron cloud.
    e. No two electrons in one atom can have the same four quantum numbers.

45. A measured mass of an unreactive metal was dropped into a small graduated cylinder half filled with water. The following measurements were made.
    Mass of metal = ...19.611 grams
    Volume of water before addition
    of metal =.....12.4 milliliters
    Volume of water after addition
    of metal =.....14.9 milliliters

    The density of the metal should be reported as
    a. 7.8444 grams per mL
    b. 7.844 grams per mL
    c. 7.84 grams per mL
    d. 7.8 grams per mL
    e. 8 grams per mL

1993 A
Elemental analysis of an unknown pure substance indicated that the percent composition by mass is as follows.

Element	Percent by Mass
Carbon	49.02%
Hydrogen	2.743%
Chlorine	48.23%

A solution that is prepared by dissolving 3.150 grams of the substance in 25.00 grams of benzene, C_6H_6, has a freezing point of 1.12°C. (The normal freezing point of benzene is 5.50°C and the molal freezing-point depression constant, K_f, for benzene is 5.12°C/molal.)

(a) Determine the empirical formula of the unknown substance.

*(b) Using the data gathered from the freezing-point depression method, calculate the molar mass of the unknown substance.

*(c) Calculate the mole fraction of benzene in the solution described above.

*(d) The vapor pressure of pure benzene at 35°C is 150. millimeters of Hg. Calculate the vapor pressure of benzene over the solution described above at 35°C.

*these are here for examples… we haven't reviewed or covered this material yet in AP

Another Free Response type question

For questions 1 and 2, write the LEFT side of the equation. You do NOT need to predict the products and balance (yet!). *(The actual AP test question will ask you to predict the products and write a completed equation. Since we are not that far yet, we're only doing the first step.)

a) iron(III) ions are reduced by iodide ions.

f) excess water is added to solid calcium hydride.

ANSWERS:

33) a 45) d

1st Free Response:

(a) moles / 100 g C H Cl
49.02/12.01 2.743/1.008 48.23/35.45
= 4.081 = 2.722 = 1.360
mol ratio 3 2 1
empirical formula: C_3H_2Cl

(b) $\Delta T_f = (K_f)(m)$

$$4.38^\circ = \left(5.12^\circ/_{\text{molal}}\right) \times \frac{3.150^{\text{g}}/_{\text{molmass}}}{0.02500\text{kg}} = 147^{\text{g}}/_{\text{mol}}$$

(c) mol fraction = mol benzene / total mol $= \dfrac{25.00/78.11}{\frac{3.150}{147} + \frac{25.00}{78.11}} = 0.938$

(d) vapor pressure = mol fraction $\times$ P_o = (0.938)(150 mm) = 141 mm

2nd Free Response:

$Fe^{3+}(aq) + I^-(aq) \rightarrow$
$CaH_2(s) + H_2O \rightarrow$

AP Chemistry – Chapter 3, Stoichiometric Relationships Study Guide

- Convert grams to moles, moles to grams, atoms to moles, moles to atoms, atoms to grams, grams to atoms for an element
- Know the value and definition of Avogadro's number.
- Calculate the average atomic mass of an element when given natural abundance of each isotope.
- Find the molecular mass of a compound.
- Find the empirical and molecular formulas from grams and from % composition.
- Explain mole ratio
- Stoichiometry: Calculate theoretical yields when given the limitng reactant (Convert: moles A to moles B, grams A to moles B, moles A to grams B, grams A to grams B)
- Explain limiting reactant and excess.
- Calculate theoretical yields by finding the limiting reactant
- Calculate percent yield.
- Calculate stoichiometric problems using density of a gas at STP.
- List factors that affect solubility

Sample AP Problems (copyright College Board)

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, $Ca(NO_3)_2$, 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

37. __ $CH_3CH_2COOH(l)$ + __ $O_2(g)$ ---> __ $CO_2(g)$ + __ $H_2O(l)$
How many moles of O_2 are required to oxidize 1 mole of CH_3CH_2COOH according to the reaction represented above?

(A) 2 moles
(B) 5/2 moles
(C) 3 moles
(D) 7/2 moles
(E) 9/2 moles

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) $Na_2CO_3 \cdot 10\ H_2O$
(B) $Na_2CO_3 \cdot 7\ H_2O$
(C) $Na_2CO_3 \cdot 5\ H_2O$
(D) $Na_2CO_3 \cdot 3\ H_2O$
(E) $Na_2CO_3 \cdot H_2O$

1998. 2) An unknown compound contains only the three elements C,H, and O. A pure sample of the compound is analyzed and found to be 65.60 percent C and 9.44 percent H by mass.

(a) Determine the empirical formula of the compound.

(b) A solution of 1.570 grams of the compound in 16.08 grams of camphor is observed to freeze at a temperature 15.2 Celsius degrees below the normal freezing point of pure camphor. Determine the molar mass and apparent molecular formula of the compound. (The molal freezing-point depression constant, K_f, for camphor is 40.0 kg-K-mol^{-1}.)

(c) When 1.570 grams of the compound is vaporized at 300 °C and 1.00 atmosphere, the gas occupies a volume of 577 milliliters. What is the molar mass of the compound based on this result?

(d) Briefly describe what occurs in solution that accounts for the difference between the results obtained in parts (b) and (c).

Stiochiometry Answers:
15) C 23) E 24) B 25) D 37) D 39) B

2)
(a) Assume a 100 gram sample (not necessary for credit):
65.60g C x (1 mol C / 12.01 g C) = 5.462 mol C
9.44g H x (1 mol H / 1.0079 g H) = 9.366 mol H
mass O = [100 - (65.60 + 9.44)] = 24.96 g O
24.96 g O x (1 mol O / 15.9994 g O) = 1.560 mol O
$C_{5.462}H_{9.366}O_{1.560}$ ---> $C_{3.5}H_{6.0}O_{1.0}$ ---> $C_7H_{12}O_2$

One point earned for determining moles of C and moles of H
One point earned for determining moles of O
One point earned for correct empirical formula

(b) m = ▫T / K_f = 15.2 °C /40.0 K kg mol^{-1} = 0.380 mol / kg
0.01608 kg x (0.380 mo / 1 kg) = 0.00611 mol
molar mass = 1.570 g/ 0.00611 mol = 257 g / mol

One point earned for determination of molarity
One point earned for conversion of molarity to molar mass

OR,
moles solute = (▫T x kg solvent) / K_f = 0.00611 mol (one point)
molar mass = 1.570 g / 0.00611 mol = 257 g / mol (one point)
OR,
molar mass = (mass x K_f) / (▫T x kg solvent) = 257 g / mol (two points)
empirical mass of $C_7H_{12}O_2$ = 7(12) + 12(1) + 2(16) = 128 g/mol
128 g/mol = 1/2 molar mass ---> molecular formula = 2x (empirical formula) -----> molecular formula = $C_{14}H_{24}O_4$ (one point)

One point earned if molecular formula is wrong but is consistent with empirical formula and molar mass
No penalty for simply ignoring the van't Hoff factor
Only one point earned for part (b) if response indicates that ▫T= (15.2 + 273) = 288 K and molar mass = 13.6 g / mol

(c) n = (pV) / (RT) = [(1 atm) (0.577 L)] / [(0.0821 L atm mol^{-1} K^{-1}) (573 K)] = 0.0123 mol (one point)
molar mass = mass of sample / moles in sample = 1.570 g / 0.0123 mol = 128 g/mol (one point)

Only one point can be earned for part (c) if wrong value for R is used and/or T is not converted from C to K

(d) The compound must form a dimer in solution, because the molar mass in solution is twice that it is in the gas phase,
OR,
the compound must dissociate in the gas phase (A (g) --> 2B (g)) because the molar mass in the gas phase is half that it is in solution.

One point earned for a reference to either or both the ideas of dimerization and dissociation -
No point earned for a " non - ideal behavior " argument

Study Guide: Chapter 4, Chemical Reactions (minus Solution Stoichiometry)

Students should be able to...

- **Predict the products and balance these types of molecular equations: synthesis (addition), decomposition, metathesis (single replacement, double replacement), and combustion (see handout: http://www.chem.vt.edu/RVGS/ACT/notes/Types_of_Equations.html)**
- **Use solubility rules to determine dissolution of ions in ionic compounds**
- **Write and balance total and net ionic equations**
- **Determine oxidation numbers**

Sample Problems

Equations – see other study guide for review problems and AP sample problems

(1984) 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) $Ag_2CO_3(s) + 2\ H^+ \rightarrow 2Ag^+ + H_2CO_3$

Find the oxidation numbers for each element in each compound.

1. **$FeSO_4$**
2. **KNO_2**
3. **$Na_2Cr_2O_7$**

(1987) 4) Use appropriate ionic and molecular formulas to show the reactants and the products for the following, each of which occurs in aqueous solution except as indicated. Omit formulas for any ionic or molecular species that do not take part in the reaction. You need not balance. In all cases a reaction occurs.

a) Solid calcium is added to warm water.

b) Powdered magnesium oxide is added to a container of carbon dioxide gas.

c) Gaseous hydrogen sulfide is bubbled through a solution of nickel(II) nitrate.

e) Solid silver is added to a dilute nitric acid (6M) solution.

g) Hydrogen peroxide (an oxidizing agent) solution is added to a solution of iron(II) sulfate.

h) Propanol (C_3H_7OH) is burned completely in air.

Answers: (32) A; (1) Fe = +2, S = +6, O = -2; (2) K = +1, N = +3, O = -2; (3) Na = +1, Cr = +6 , O = -2;

4) (answers are unbalanced)
a) $Ca + H_2O$ ---> $Ca(OH)_2 + H_2$
$Ca^{2+} + OH^-$ earns one point

b) $MgO + CO_2$ ---> $MgCO_3$

c) $H_2S + Ni^{2+}$ ---> $NiS + H^+$

e) $Ag + H^+ + NO_3^-$ ---> $Ag^+ + NO$ (or NO_2) + H_2O

1 product = 1 pt
2 products = 1 pt
3 products = 2 pts

g) $H_2O_2 + Fe^{2+}$ ---> $Fe^{3+} + H_2O$

$Fe(OH)_3$ only as a product earns one point (Note: the scoring standard on this question has a two next to the formula, but in context of below, a one seems more appropriate)

h) $C_3H_7OH + O_2$ ---> $CO_2 + H_2O$

spurious products: minus 1 pt.
2 pts for correct molecular equation where ionic equation is apropriate

AP Chemistry Reactions FAQ

Q: What are the types of reactions and what turns into what?
Q: What are the "special cases" for each type of reaction?

A: Refer to the handout http://www.chem.vt.edu/RVGS/ACT/notes/Types_of_Equations.html
This is an excellent list of all the types of reactions and what the products are. The special cases are: under synthesis #3 and #4; decomposition #1, 2, 3, and 4; single replacement #2, and ionic (double replacement) #4. All the others are just examples that follow the same general trend.

Q: When would you use strong acids & bases?

A: In reactions, strong acids and strong bases almost totally split into ions. To be classified as a "strong" acid or base, 95% or more of the molecules must split into ions when in water. In industry, strong acids and bases are used for many things including etching, dissolving metals, catalysts, metal refining, batteries, water treatment, cleaning, and many, many others.

Study Guide for AP Chemistry – Chapter 5, Gas Laws

Students should be able to...

- Explain the kinetic theory of matter as it applies to gases.
- Identify the properties of an ideal gas vs. a real gas
- Know units of pressure in atm, torr, mm Hg, and kPa,
- Calculate using Boyle's Law, Charles' Law, Gay-Lussac's Law, Combined Gas Law, and Ideal Gas Law (using 0.0821 for R).
- Change gases to STP.
- Calculate partial pressure of a gas using Dalton's Law.
- Calculate stoichiometric problems using density of a gas at STP.
- Calculate relative speed using Graham's Law.
- Calculate the average kinetic energy of the molecules of a gas
- Find the molar volume of a gas (laboratory)

Sample AP Problems – Copyright College Board

Multiple Choice – 1989

16. A gaseous mixture containing 7.0 moles of nitrogen, 2.5 moles of oxygen, and 0.50 mole of helium exerts a total pressure of 0.90 atmosphere. What is the partial pressure of the nitrogen?

(A) 0.13 atm
(B) 0.27 atm
(C) 0.63 atm
(D) 0.90 atm
(E) 6.3 atm

30. Hydrogen gas is collected over water at 24 °C. The total pressure of the sample is 755 millimeters of mercury. At 24 °C, the vapor pressure of water is 22 millimeters of mercury. What is the partial pressure of the hydrogen gas?

(A) 22 mm Hg
(B) 733 mm Hg
(C) 755 mm Hg
(D) 760 mm Hg
(E) 777 mm Hg

32. A 2.00-liter sample of nitrogen gas at 27 °C and 600. millimeters of mercury is heated until it occupies a volume of 5.00 liters. If the pressure remains unchanged, the final temperature of the gas is

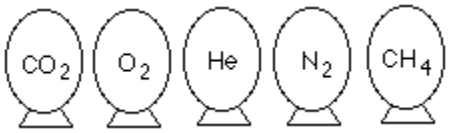
(A) 68 °C
(B) 120 °C
(C) 477 °C
(D) 677 °C
(E) 950. °C

40. $2\ K + 2\ H_2O \rightarrow 2\ K^+ + 2\ OH^- + H_2$
When 0.400 mole of potassium reacts with excess water at standard temperature and pressure as shown in the equation above, the volume of hydrogen gas produced is

(A) 1.12 liters
(B) 2.24 liters
(C) 3.36 liters
(D) 4.48 liters
(E) 6.72 liters

Free Response – 1996

5)



Represented above are five identical balloons, each filled to the same volume at 25°C and 1.0 atmosphere pressure with the pure gas indicated.
(a) Which balloon contains the greatest mass of gas? Explain.
(b) Compare the average kinetic energies of the gas molecules in the balloons. Explain.
(c) Which balloon contains the gas that would be expected to deviate most from the behavior of an ideal gas? Explain.
(d) Twelve hours after being filled, all the balloons have decreased in size. Predict which balloon will be the smallest. Explain your reasoning.

Answers:
16. C
30. B
32. C
40. D

5)
(a) two points
CO_2
because all contain same number of molecules (moles), and CO_2 molecules are the heaviest
Note: total of 1 point earned if CO_2 not chosen but same number of molecules (moles) is specified

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(b) two points
All are equal
because same temperature, therefore same average kinetic energy
Note: just restatement of "same conditions, etc." does not earn second point

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(c) two points
CO_2
either one:

- it has the most electrons, hence is the most polarizable
- it has the strongest intermolecular (London) forces

Note: also allowable are "polar bonds", "inelastic collisions"; claiming larger size or larger molecular volume does not earn second point

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(d) two points
He
Any one:

- greatest movement through the balloon wall
- smallest size
- greatest molecular speed
- most rapid effusion (Graham's law)

AP Chapter 6 Thermodynamics study guide

Students should be able to...

* Calculate the specific heat of a substance.
* Define: enthalpy, entropy, heat of fusion, heat of vaporization, Hess's Law, exothermic, endothermic.
* Know the First law of thermodynamics
* Calculate the heat required to heat water in all 3 phases, and between phases
* Label an energy diagram (exothermic and endothermic)
* Determine the change in standard enthalpy of a reaction (delta H)
* Determine the heat of combustion for a reaction
* Determine if the reaction is exothermic or endothermic when given delta H
* Use Hess' Law to determine reaction energies
* Find the specific heat of a metal (laboratory)
* Find the heat of fusion of ice (laboratory)

Sample AP problems:

1998-3) $C_6H_5OH(s) + 7\ O_2(g) \rightarrow 6\ CO_2(g) + 3H_2O(l)$

When a 2.000-gram sample of pure phenol, $C_6H_5OH(s)$, is completely burned according to the equation above, 64.98 kilojoules of heat is released. Use the information in the table below to answer the questions that follow.

Substance	Standard Heat of Formation, DH°_f, at 25°C (kJ/mol)	Absolute Entropy, S°, at 25°C (J/mol-K)
C(graphite)	0.00	5.69
$CO_2(g)$	-395.5	213.6
$H_2(g)$	0.00	130.6
$H_2O(l)$	-285.85	69.91
$O_2(g)$	0.00	205.0
$C_6H_5OH(s)$	?	144.0

(a) Calculate the molar heat of combustion of phenol in kilojoules per mole at 25°C.
(b) Calculate the standard heat of formation, DH°_f, of phenol in kilojoules per mole at 25°C.
(c) Calculate the value of the standard free-energy change, DG° for the combustion of phenol at 25°C.
(d) If the volume of the combustion container is 10.0 liters, calculate the final pressure in the container when the temperature is changed to 110°C. (Assume no oxygen remains unreacted and that all products are gaseous.)

1994-25.

$H_2(g) + (1/2)\ O_2(g)$ ---> $H_2O(l)$ $DH^\circ = -286$ kJ

$2\ Na(s) + (1/2)\ O_2(g)$ ---> $Na_2O(s)$ $DH^\circ = -414$ kJ

$Na(s) + (1/2)\ O_2(g) + (1/2)\ H_2(g)$ ---> $NaOH(s)$ $DH^\circ = -425$ kJ

Based on the information above, what is the standard enthalpy change for the following reaction?

$$Na_2O(s) + H_2O(l) \text{ ---> } 2\ NaOH(s)$$

(A) -1,125 kJ
(B) -978 kJ
(C) -722 kJ
(D) -150 kJ
(E) +275 kJ

1994-35. For which of the following processes would DS have a negative value?

I. $2\ Fe_2O_3(s)$ ---> $4\ Fe(s) + 3\ O_2(g)$

II. $Mg^{2+} + 2\ OH^- \text{ ---> } Mg(OH)_2(s)$

III. $H_2(g) + C_2H_4(g)$ ---> $3\ C_2H_6(g)$

(A) I only
(B) I and II only
(C) I and III only
(D) II and III only
(E) I, II, and III

1994-58. $N_2(g) + 3\ H_2(g)$ ---> $2\ NH_3(g)$

The reaction indicated above is thermodynamically spontaneous at 298 K, but becomes nonspontaneous at higher temperatures. Which of the following is true at 298 K?

(A) DG, DH, and DS are all positive.
(B) DG, DH, and DS are all negative.
(C) DG and DH are negative, but DS is positive.
(D) DG and DS are negative, but DH is positive.
(E) DG and DH are positive, but DS is negative.

AP Thermodynamics Study Guide Answers

1998 #3

(a) 2.000g x (1 mol / 94.113 g) = 0.02125 mol phenol (one point)

Heat released per mole = 64.98kJ / 0.02125mol = 3,058 kJ/mol (one point)

or, DH_{comb} = - 3,058 kJ/mol

Units not necessary

(b) DH_{comb} = - 3,058 kJ/mol (one point)

- 3,058 kJ = [6 (-395.5) + 3 (-285.85)] - [DH°_{f} phenol] (one point)

DH°_{f} phenol = - 161 kJ (one point) (math error????? - 173 kJ)

One point earned for correct sign of heat of combustion, one point for correct use of moles/coefficients, and one point for correct substitution

(c)DS° = [3 (69.91) + 6 (213.6)] - [7 (205.0) + 144.0] = - 87.67 J/K (one point)

$DG^{\circ} = DH^{\circ} - TDS^{\circ}$ = -3,058 kJ - (298 K) (-0.08767 kJ/K) = -3,032 kJ (one point)

Units not necessary; no penalty if correct except for wrong DH_{comb} from part (a)

(d) moles gas = 9 x [moles from part (a)] = 9 (0.02125 mol0 = 0.1913 moles gas (one point)
**** 9 moles because it says "assume ALL products are gaseous"

$P = (nRT) / V = [(0.193 \text{ mol}) (0.0821 \text{ L atm mol}^{-1}\text{K}^{-1}) (383 \text{ K})] / 10.0 \text{ L} = 0.601 \text{ atm}$ (one point)

Units necessary; no penalty for using Celsius temperature if also lost point in part (c) for same error

Multiple Choice

25. D

35. D *** note the reaction is not properly balanced!

58. B

AP Chemistry Study Guide – Chapter 7 and 8, Atomic Structure and Periodicity

Students should be able to …

- Find wavelength, amplitude, and frequency of a sine wave
- Discuss the electromagnetic spectrum
- Convert between frequency and wavelength
- Calculate the energy of a wave
- Calculate the energy of an electron
- Calculate the energy released in a transition of an electron from an excited state to the ground state
- Know the order of visible light by increasing energy (ROY G BIV)
- Define: ground state, excited state, Aufbau principle, Pauli exclusion principle, Heisenberg Uncertainty Principle, Hund's rule, octet rule, valence
- Discuss particle-wave nature of light.
- Know the definitions of all four quantum numbers.
- Find the values for all four quantum numbers for a chosen electron
- Know the order of filling of the orbitals (Aufbau principle/diagonal rule)
- Know the maximum number of electrons in each type of orbital.
- Find electron configurations, both longhand and shorthand, for elements and ions
- Predict the last electron in a configuration using the periodic table
- Draw orbital diagrams for elements and ions
- Know d^4, d^9, f^1, and f^8 exceptions.
- Know the direction, definition, and reasoning behind periodic trends: atomic radius, ionic radius, 1st ionization energy, electron affinity, and electronegativity

Sample AP Questions (copyright College Board)

Use these answers for questions 1 - 3.

(A) O
(B) La
(C) Rb
(D) Mg
(E) N

1. What is the most electronegative element of the above?
2. Which element exhibits the greatest number of different oxidation states?
3. Which of the elements above has the smallest ionic radius for its most commonly found ion?

Use these answers for questions 4 - 7.

(A) $1s^2\ 2s^2 2p^5\ 3s^2 3p^5$
(B) $1s^2\ 2s^2 2p^6\ 3s^2 3p^6$
(C) $1s^2\ 2s^2 2p^6 2d^{10}\ 3s^2 3p^6$
(D) $1s^2\ 2s^2 2p^6\ 3s^2 3p^6 3d^5$
(E) $1s^2\ 2s^2 2p^6\ 3s^2 3p^6 3d^3\ 4s^2$

4. An impossible electronic configuration
5. The ground-state configuration for the atoms of a transition element
6. The ground-state configuration of a negative ion of a halogen
7. The ground-state configuration of a common ion of an alkaline earth element

33. Which of the following conclusions can be drawn from J. J. Thomson's cathode ray experiments?

(A) Atoms contain electrons.
(B) Practically all the mass of an atom is contained in its nucleus.
(C) Atoms contain protons, neutrons, and electrons.
(D) Atoms have a positively charged nucleus surrounded by an electron cloud.
(E) No two electrons in one atom can have the same four quantum numbers.

Free response

6) Account for each of the following in terms of principles of atomic structure, including the number, properties, and arrangements of subatomic particles.

(a) The second ionization energy of sodium is about three times greater than the second ionization energy of magnesium.

(b) The difference between the atomic radii of Na and K is relatively large compared to the difference between the atomic radii of Rb and Cs.

(c) A sample of solid nickel chloride is attracted into a magnetic field, whereas a sample of solid zinc chloride is not.

(d) Phosphorus forms the fluorides PF_3 and PF_5, whereas nitrogen forms only NF_3.

Answers for AP Problems for Chapter 7 – Atomic Structure and Periodicity:

1. A 2. E 3. D 4. C 5. E 6. B 7. B 33. A

6) average = 2.1
a) three points
Electron configuration of Na and Mg (1 pt)
Any one earns a point:

- Octet / Noble gas stability comparison of Na and Mg
- Energy difference explanation between Na and Mg
- Size difference explanation between Na and Mg

Note: If only Na or Mg is used 1 point can be earned by showing the respective electron configuration and using one of the other explanations
Shielding/effective nuclear charge discussion earns the third point.

---

b) one point
Correct direction and explanation of any one of the following:

- shielding differences
- energy differences
- # of proton/ # of electron differences

---

c) two points
Any one set earns one point:

- (i) Ni unpaired electrons. paramagnetic
- (ii) Zn paired electrons/ diamagnetic
- (iii) Ni unpaired electrons/ Zn paired electrons
- (iiii) Ni paramagnetic/ Zn diamagnetic

Orbital discussion/ Hund's Rule/ Diagrams earns the second point.

---

d) two points
Expanded octet or sp^3d hybrid of phosphorous (1 pt)
Lack of d orbitals in nitrogen (1 pt)
OR
nitrogen is too small to accomodate (or bond) 5 Fluorines or 5 bonding sites (2 pts)

AP Chemistry Chapters 8 & 9 – Bonding Study Guide

Students should be able to...

* Define: chemical bond, ionic, covalent, metallic, diatomic, polar, nonpolar, and VSEPR
* Use electronegativity to determine the type of bond formed between two elements
* Calculate bond energies.
* Determine the polarity of a dipole.
* Draw Lewis structures for covalent molecules, including double and triple bonds.
* Draw Lewis structures for polyatomic ions
* Use formal charge to determine the best Lewis structure
* Use VSEPR chart to determine electron arrangement and molecular geometry.
* Use VSEPR chart to write Lewis structures that include bond angles. Be able to draw resonance structures for covalent molecules
* Calculate the enthalpy of formation, lattice energy, and associated information.
* Determine hybridization of orbitals within a molecule (no sp^3d or sp^3d^2)
* Identify sigma and pi bonds

Sample AP Problems from Bonding:

Questions 8-10 refer to the following diatomic species.

(A) Li_2
(B) B_2
(C) N_2
(D) O_2
(E) F_2

8. Has the largest bond-dissociation energy
9. Has a bond order of 2
10. Contains 1 sigma (s) and 2 pi (p) bonds

15. In a molecule in which the central atom exhibits sp^3d^2 hybrid orbitals, the electron pairs are directed toward the corners of

(A) a tetrahedron
(B) a square-based pyramid
(C) a trigonal bipyramid
(D) a square
(E) an octahedron

17. The Lewis dot structure of which of the following molecules shows only one unshared pair of valence electron?

(A) Cl_2
(B) N_2
(C) NH_3
(D) CCl_4
(E) H_2O_2

47. CCl_4, CO_2, PCl_3, PCl_5, SF_6 Which of the following does not describe any of the molecules above?

(A) Linear
(B) Octahedral
(C) Square planar
(D) Tetrahedral
(E) Trigonal pyramidal

Free response:

5) Consider the molecules PF_3 and PF_5.

a) Draw the Lewis electron-dot structures for PF_3 and PF_5 and predict the molecular geometry of each.

b) Is the PF_3 molecular polar, or is it nonpolar? Explain.

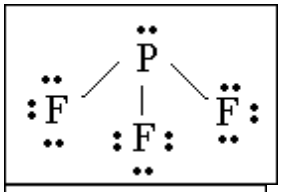
c) On the basis of bonding principles, predict whether each of the following compounds exists. In each case, explain your prediction.

(i) NF_5
(ii) AsF_5

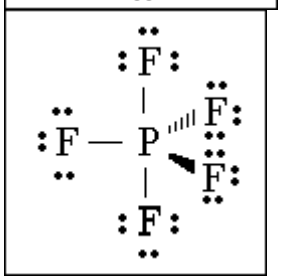
Answers to Sample AP Problems:

Multiple choice: 8) C 9) D 10) C 15) E 17) C 47. C

Free Response: 5)



(Trigonal) pyramid(al)



(Trigonal) bipyramid(al)

1 point for each structure

Note ; One point (total) deducted if lone pairs not shown on F atoms in either molecule.

(b) The PF_3 molecule is polar
The three P-F dipoles do not cancel, or,
the lone pair on P leads to asymmetrical distribution of charge.
Note; "Molecule is not symmetrical" does not earn point. Both points can be earned if answer is consistent with incorrect (a).

(c) NF_5 does not exist because no 2d orbitals exist for use in bonding, or,
N is too small to accommodate 5 bonding pairs
AsF_5 does exist because 4d orbitals are available for use in bonding, or,
As can accommodate an expanded octet using d orbitals

Note; Response with two correct predictions with no explanations earns one point. Also, argument of "no expanded octet" vs. "expanded octet" alone does not earn explanation point.

AP Chemistry – Chapter 8, Bonding FAQ

Q: How do *s* and *p* use *d* electrons in expanded octets if they don't have *d* electrons?

A: Even though sulfur and phosphorous do not have *d* electrons, there is still an empty *d* orbital present (*3d*). While it is unusual, electrons can be shared in those empty *d* orbitals to form expanded octets.

Q: How do I know which bond is more polar without using an electronegativity table?

A: Use the periodic trend for electronegativity. The higher electronegativity is the one furthest up and right on the periodic table. To find the highest polarity, find the two elements that have the largest difference in electronegativity (the furthest apart from each other on the periodic table).

Q: How do bond energies work?

A: The bond energies obtained by breaking all the bonds in the reactants (left side of the arrow) minus all the energy needed to form bonds (on the right side of the arrow) would equal the net change in energy. If there are coefficients, be sure to multiply the bond energy of the molecule by the number of moles of that molecule present.

Q: What do I do if I get a tie between two different structures when evaluating formal charge?

A: First, keep in mind that the "true" structure is an average of all the possible structures. If one of the structures IS the average of all the structures, then it must be the best one. (Example: two double bonds, a triple bond and a single bond, and a single bond and a triple bond would average out to two double bonds.) If that doesn't break the tie, then go with the structure that would best suit the element's charge. (Example: If it's between C and O having a negative formal charge, O would be the better choice to be negative since it's more electronegative.)

Q: How do I draw a Lewis structure of an ion?

A: If it's a negative ion, add the negative charge to the valence. If it's a positive ion, subtract the positive charge from the valance. In either case put [ ] around the entire structure, and write the charge outside the brackets.

Q: How do I find the formal charge of an element?

A: Group number – lone electrons (dots) – ½ of the bonded electrons

Q: How do I use formal charge to determine the central atom?

A: Draw all the possible structures, trying each one in the center. Find the formal charge for each structure. Whichever structure has the least amount of formal charge (often the least number of atoms that have formal charge) is the best structure. (NOTE: All of the structures should add up to the same charge… zero for a compound, or the charge of the ion if it's an ion)

AP Chemistry – Chapter 10, Liquids and Solids (Intermolecular Attractions) Study Guide

Students should be able to...

* Define: polar, nonpolar, dipole-dipole forces, ion-dipole forces, Hydrogen "bonding", and London dispersion forces; sublimation, condensation, freezing point, boiling point, vapor pressure, fusion, vaporization
* Distinguish between intermolecular and intramolecular attractions
* Put a list of compounds in order of increasing melting point, boiling point, and vapor pressure
* Use and label the parts of a phase diagram (not on AP, but on my test)
* Understand the expansion of ice due to hydrogen bonding
* Understand the different types of solids that can form and the associated intermolecular attractions

Sample AP Problems (Copyright College Board)

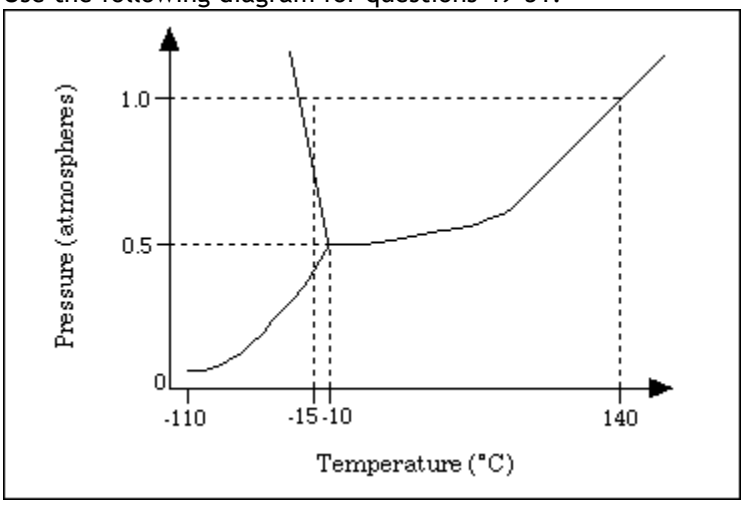
Use these answers for questions 11 - 14.

(A) hydrogen bonding
(B) hybridization
(C) ionic bonding
(D) resonance
(E) van der Waals forces (London dispersion forces)

11. Is used to explain why iodine molecules are held together in the solid state
12. Is used to explain why the boiling point of HF is greater than the boiling point of HBr
14. Is used to explain the fact that the carbon-to-carbon bonds in benzene, C_6H_6, are identical
21. Which of the following is true at the triple point of a pure substance?

(A) The vapor pressure of the solid phase always equal the vapor pressure of the liquid phase.
(B) The temperature is always 0.01 K lower that the normal melting point.
(C) The liquid and gas phases of the substance always have the same density and are therefore indistinguishable.
(D) the solid phase always melts if the pressure increases at constant temperature.
(E) The liquid phase always vaporizes if the pressure increases at constant temperature.

Use the following diagram for questions 49-51.



49. The normal boiling point of the substance represented by the phase diagram above is

(A) -15 °C
(B) -10 °C
(C) 140 °C (continued on next page)
(D) greater than 140 °C
(E) not determinable from the diagram

50. The phase diagram above provides sufficient information for determining the

(A) entropy change on vaporization
(B) conditions necessary for sublimation
(C) deviations from ideal gas behavior of the gas phase
(D) latent heat of vaporization
(E) latent heat of fusion

51. For the substance represented in the diagram, which of the phases is most dense and which is least dense at -15 °C.

	Most Dense	Least Dense
(A)	Solid	Gas
(B)	Solid	Liquid
(C)	Liquid	Solid
(D)	Liquid	Gas
(E)	The diagram gives no information about densities.	

1992 free response (Copyright College Board)

8) Explain each of the following in terms of atomic and molecular structures and/or intermolecular forces.
(a) Solid K conducts an electric current, whereas solid KNO_3 does not.
(b) $SbCl_3$ has a measurable dipole moment, whereas $SbCl_5$ does not.
(c) The normal boiling point of CCl_4 is 77 °C, whereas that of CBr_4 is 190 °C.
(d) NaI(s) is very soluble in water whereas I_2(s) has a solubility of only 0.03 gram per 100 grams of water.

Answers to AP problems
Multiple Choice Answers: E, A, D, A, C, B, D

Free Response 8) average score = 3.0
a) two points
K conducts because of its metallic bonding or "sea" of mobile e's (or "free" e's)
KNO_3 does not conduct because it is ionically bonded and has immobile ions (or imm. e's)

---

b) two points
$SbCl_3$ has a measurable dipole moment because it has a lone pair of e's which causes a dipole
or its dipoles do not cancel
or it has a trigonal pyramidal structure
or clear diagram illustrating any of the above
$SbCl_5$ has no dipole moment because its dipoles cancel
or it has a trigonal bipyramidal structure
or clear diagram illustrating either of the above

---

c) two points
CBr_4 boils at a higher T than CCl_4 because it has stronger intermolecular forces (or van der Waals or London dispersion). These stronger forces occur because CBr_4 is larger and/or has more electrons than CCl_4. (Note added to scoring standard: student misconception of inter-, with "inter-" double underlined.)

d) two points

NaI has greater aqueous solubility than I_2 because NaI is ionic (or polar) whereas I_2 is nonpolar (or covalent). H_2O, being polar, interacts with the ions of NaI but not with I_2. (Like dissolves like accepted if polarity of H_2O clearly indicated.)

AP Chemistry study guide for Solutions (Chapter 11) & Solution Stoich (Chapter 4b)

Students should be able to...

- Define: solute, solvent, solution, electrolyte, nonelectrolyte, types of solutions (combinations of matter states), suspension, colloid, Brownian movement, saturated, unsaturated, supersaturated, miscible, immiscible, Tyndall effect, hypertonic, hypotonic, isotonic
- Know the factors that affect solubility
- Calculate Molarity.
- Calculate mole fraction.
- Calculate titration data
- Explain the nonideal behavior of solutions

Sample AP problems

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

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

36. Appropriate laboratory procedures include which of the following?

I. Rinsing a buret with distilled water just before filling it with the titrant for the first titration
II. Lubricating glass tubing before inserting it into a stopper
III. For accurate results, waiting until warm or hot objects have reached room temperature before weighing them

(A) II only
(B) I and II only
(C) I and III only
(D) II and III only
(E) I, II, and III

43. Which of the following does NOT behave as an electrolyte when it is dissolved in water?

(A) CH_3OH
(B) K_2CO_3
(C) NH_4Br
(D) HI
(E) Sodium acetate, CH_3COONa

67. $BrO_3^- + 5\ Br^- + 6\ H^+ \text{ <===> } 3\ Br_2 + 3\ H_2O$
If 25.0 milliliters of 0.200-molar BrO_3^- is mixed with 30.0 milliliters of 0.450-molar Br^- solution that contains a large excess of H^+, the amount of Br_2 formed, according to the equation above, is

(A) 5.00×10^{-3} mole
(B) 8.10×10^{-3} mole
(C) 1.35×10^{-2} mole
(D) 1.50×10^{-2} mole
(E) 1.62×10^{-2} mole

72. How many moles of solid $Ba(NO_3)_2$ should be added to 300. milliliters of 0.20-molar $Fe(NO_3)_3$ 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

Free Response Question (copyright College Board)

2008 part A form B question #3

A 0.150 g sample of solid lead(II) nitrate is added to 125 mL of 0.100 *M* sodium iodide solution. Assume no change in volume of the solution. The chemical reaction that takes place is represented by the following equation.

$$Pb(NO_3)_2(s) + 2\ NaI(aq) \rightarrow PbI_2(s) + 2\ NaNO_3(aq)$$

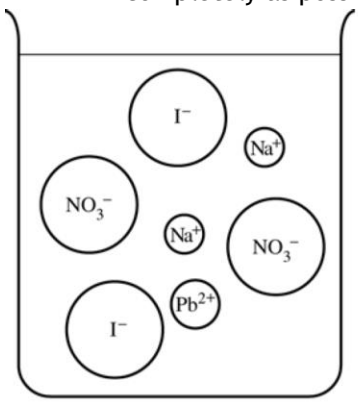
(a) List an appropriate observation that provides evidence of a chemical reaction between the two compounds.

(b) Calculate the number of moles of each reactant.

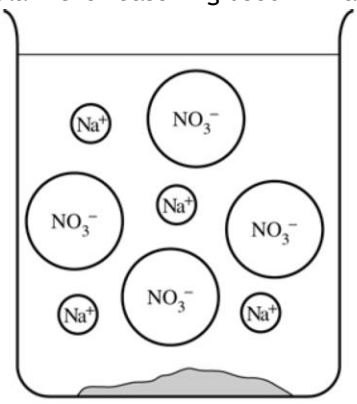
(c) Identify the limiting reactant. Show calculations to support your identification.

(d) Calculate the molar concentration of $NO_3^-(aq)$ in the mixture after the reaction is complete.

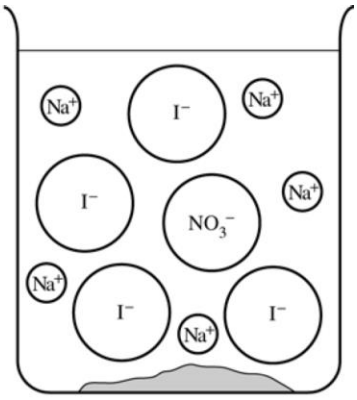
(e) Circle the diagram below that best represents the results after the mixture reacts as completely as possible. Explain the reasoning used in making your choice.



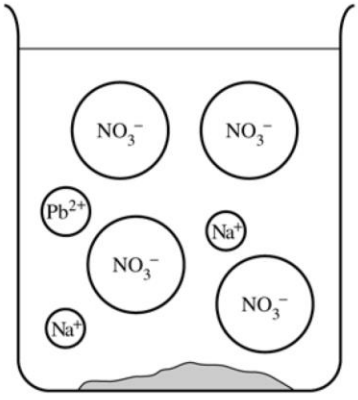
No Precipitate



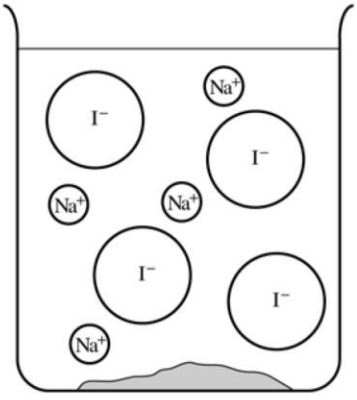
Solid PbI_2



Solid PbI_2



Solid PbI_2



Solid $Pb(NO_3)_2$

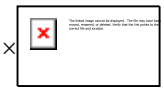
Chapter 11/4b AP Sample Problem Answers

15. C
26. C
36. D
43. A
67. B
72. A

Free response answer:

(a) formation of a yellow ppt

(b) 0.150 g $Pb(NO_3)_2 \times$  $= 4.53 \times 10^{-4}$ mol $Pb(NO_3)_2$

0.125 mL $\times$  = 0.0125 mol NaI

(c) $Pb(NO_3)_2$; since they react in a 1:2 ratio of $Pb(NO_3)_2$:NaI, 6.25×10^{-3} mol $Pb(NO_3)_2$ would be required to react with all the NaI, therefore, you would run out of the lead nitrate first

(d) the nitrate is a spectator ion,  $= 7.25 \times 10^{-3}$ *M*

AP Chemistry – Solutions, Chapter 11/4b FAQ

Q: What are hydrophobic and hydrophilic?

A: Hydrophobic is a "fear of water". Nonpolar substances are typically hydrophobic. They are not attracted to water. Hydrophilic on the other hand are "water lovers". These compounds are attracted to water, and therefore are commonly ionic or polar.

Q: How do you determine is a substance will act as an electrolyte in a solution?

A: Electrolytes must have a difference in electronegativity. The bigger the difference, the better it can conduct. Usually, nonpolar substances are considered nonelectrolytes. These are commonly organic (carbon based) molecules. Polar substances are usually fair electrolytes. These substances would have lone pairs on one end of the molecule, and a shortage on the other end. Ionic substances are very good electrolytes. Ionic substances have large electronegativity differences, and may contain polyatomic ions of course.

AP Chemistry Study Guide – Kinetics Chapter 12

Students should be able to...

- Define: activation energy, rate constant, rate of reaction
- Write a rate law for an equation
- Find the order of a reaction
- Know factors that affect reaction rate
- Determine the half-life of a reaction
- Calculate the remaining concentration of a material, given its half-life
- Calculate the time required for a concentration to be reached, given its half-life
- Calculate the concentration remaining at a given time
- Be familiar with reaction mechanisms.
- Identify catalysts and intermediates when given a mechanism.
- Find the rate determining step of a mechanism
- Determine the activation energy of a reaction
- Identify the following on an energy diagram: delta H, activation energy, use of catalyst or inhibitor

Kinetics FAQ

Q: How do I find the order of a reactant?

A: The order of a reactant is found using a table of experimental data. In short, the order is the power to which you raise the change in concentration to equal the change in the rate. For more detail, read on…

First, you must have a table of experimental data that shows 1) the concentration of all the reactants, and 2) the rate of the reaction. If only times are given, you will need to find the change in the Molarity divided by the change in time to get the rate. (Normally a table provides the rates for you, but not always.)

Once you have a table like this one below, we can see what effect the change in concentration had on the rate.

$2ClO_2(aq) + 2OH^-(aq) \rightarrow ClO_3^-(aq) + ClO_2^-(aq) + H_2O$

$[ClO_2]$ (M)	$[OH^-]$ (M)	Rate (mol/L*s)
0.010	0.030	$6.00*10^{-4}$
0.010	0.060	$1.20*10^{-3}$
0.030	0.060	$1.08*10^{-2}$

The question we need to ask is… What effect did this reactant have on the rate of the reaction? So, we need to select data from the experiment in which only ONE reactant was changed at a time. If more than 1 reactant is changed at a time, you won't be able to tell which one caused the change. Let's take a look…

First: What effect does [OH-] have on the rate? The ONLY difference in the concentrations in trial one and trial two was that the concentration of OH- was doubled. What did that do to the rate? Well, the rate doubled. This is called *first order*. The change in the concentration is equal to the change in the rate.

2 (times the conc) to what power = 2 (times the rate)

2 to the first power = 2. The power, or order, is thus 1.

Please note that the concentration of the other reactant (ClO_2) was held constant. You can only observe one change at a time!

So, now we know that OH- is first order. We can fill in the exponent now on the rate law with a 1:

$$\text{Rate} = k\,[ClO_2]^{?}\,[OH\text{-}]^{1}$$

Second: What effect does $[ClO_2]$ have on the rate? For this one, we need to look at trials two and three, where the concentration of ClO_2 is changed. (Note that this time OH- has to be constant!) Between trials two and three, the concentration of ClO_2 tripled. What happened to the rate? It went up NINE times! Tripling the concentration caused a nine time change in the rate. So, 3 to what power equals nine? 2. This is called *second order*. The change in the concentration has a squared affect on the rate.

So, the rate law can now be completed:

$$\text{Rate} = k\,[ClO_2]^{2}\,[OH^-]^{1}$$

There are other orders, but we usually deal with 1st order, 2nd order, and zero order. Zero order is when the concentration is changed, but the rate doesn't change at all.

Q: How do I determine what is an intermediate and what is a catalyst in a mechanism?

A: **Intermediates and catalysts do not appear in the overall reaction equation. An intermediate is a "temporary product". It is formed in one step, and then it is used up in a later step. So it appears on the right side of an equation, and then in a later step it is on the left side. The net result is that they cancel out.**

In class, we compared an intermediate to cookie dough. You can't just throw all the ingredients for cookies in the oven and expect cookies to come out. First, you have to make an intermediate… cookie dough. The ingredients have to be mixed, and form something temporary that can be used later on to do something else. When you get done, the cookie dough is gone… you're just left with cookies. But in order for the cookies to be made, it had to take the form of dough at some point.

A catalyst is just the opposite. A catalyst is something that lowers the activation energy of a reaction, which makes it easier to happen. A catalyst is unique in that it goes into a reaction, but always comes back out in the same form. So, a catalyst can be spotted in a reaction as going in on the left side of an equation, and in a later step it comes back out on the right side. Just like an intermediate, a catalyst will not be in the overall reaction. It cancels out.

Here's a mechanism. This is how CFC's react with ozone in the upper atmosphere.

$Cl + O_3$ --> **ClO** + O_2

O + **ClO** --> $Cl + O_2$

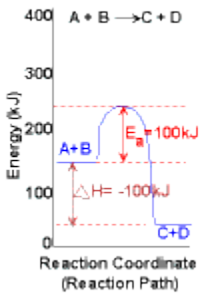
ClO is an intermediate. It doesn't appear in the overall equation. It is produced in step 1, and then used right back up in step 2. Cl is a catalyst. It went into the reaction in step 1, and came out later in step 2 in the same form.

Q: What is an energy diagram, and what does it tell me?

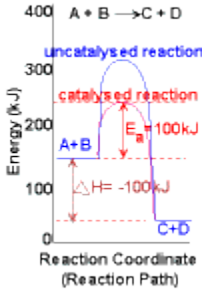
A: An energy diagram is a plot of the amount of energy present that starts with all reactants at the beginning (left side of x-axis), and progresses toward all products at the end (right side of x-axis). If you start at a high energy and end at a low energy (energy is on the y-axis), you have an exothermic reaction. Energy is released. If you start low and go high, you have an endothermic reaction. Energy is absorbed by the system.

Activation energy is the energy needed to start the reaction. This is the peak of the diagram. A reaction will not take place unless this energy is present. Once the reaction gets enough energy to go over the top, the reaction will continue on until it reaches equilibrium.

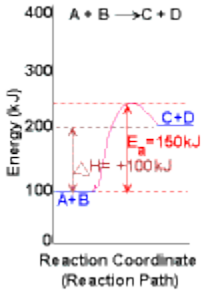
Here is an example:



Ea is the activation energy… the amount of energy from the beginning to the top of the highest peak, a.k.a "The Hump" Since the curve started out high and ended up low, it is exothermic.



A catalyst's job is to lower the activation energy. So, if a catalyst were added to this reaction, the "hump" would be smaller. An inhibitor does the opposite. It raises the activation energy in an effort to stop or slow down a reaction. It would raise the "hump" in the curve.



In an endothermic reaction, the energy starts off low and grows higher. The entire amount of energy gained is the activation energy.

Q: What is the relationship of the rate constant to the slope of the straight line?

A: In a zero order or first order reaction, the slope of the straight line is the negative of the rate constant, k. In a second order reaction, the slope is k.

In order to get a straight line, you must plot different things. In a zero order reaction, [A] vs. time should be plotted. For first order, ln [A] vs. time is needed. In second order reactions, the reciprocal of [A] (1/[A]) vs. time provides a linear line.

Q: Which equation do I use?

A: If you're solving for concentration, a regular plain 'ol rate law is usually the easiest way. Rate = k $[A]^x$ $[B]^y$… But, if you're asked a time question (how long does it take for half of it to decompose..) an integrated rate law is the way to go.

If you use an integrated rate law, you need to first determine the order of the reaction. Pick the integrated rate law for whatever order you have.

If the problem says it's a half-life decomposition, save yourself some time and go for the half-life integrated rate law.

Q: Can you do another half-life problem?

A. Yes, I can.

----THE END----

Just kidding!!!!!!!!!!! Yes, here is one!

A substance decomposes by first order half-life. How long does it take for 70% of the substance to decompose? (The half life of the substance is 8000 seconds.)

First, you need to find k.

For first order half life, half life = 0.693 / k

8000 sec = 0.693 / k

k = 8.66 X 10^{-5}

Now, we can use the integrated rate law to find t.

Ln [A/Ao] = - kt

Since 70% is gone, only 30% is to remain. Let's assume you started with 100g. So, 100g would be the original amount present. If 30% remains, you'd have 30 g remaining at time "t".

Ln [30/100] = -kt

Substitute in for k…

Ln 0.3 = - (8.66 X 10^{-5}) t

-1.204 = -8.66 X 10^{-5} t

-1.204 / -8.66 X 10^{-5} = t

13900 sec = t

Sample AP problems

17. Relatively slow rates of chemical reaction are associated with which of the following?

(A) The presence of a catalyst
(B) High temperature
(C) High concentration of reactants
(D) Strong bonds in reactant molecules
(E) Low activation energy

23.
Step 1: $Ce^{4+} + Mn^{2+} \rightarrow Ce^{3+} + Mn^{3+}$
Step 2: $Ce^{4+} + Mn^{3+} \rightarrow Ce^{3+} + Mn^{4+}$
Step 3: $Mn^{4+} + Tl^{+} \rightarrow Tl^{3+} + Mn^{2+}$
The proposed steps for a catalyzed reaction between Ce^{4+} and Tl^{+} are represented above. The products of the overall catalyzed reaction are

(A) Ce^{4+} and Tl^{+}
(B) Ce^{3+} and Tl^{3+}
(C) Ce^{3+} and Mn^{3+}
(D) Ce^{3+} and Mn^{4+}
(E) Tl^{3+} and Mn^{2+}

49. The isomerization of cyclopropane to propylene is a first-order process with a half-life of 19 minutes at 500 °C. The time it takes for the partial pressure of cyclopropane to decrease from 1.0 atmosphere to 0.125 atmosphere at 500 °C is closest to

(A) 38 minutes
(B) 57 minutes
(C) 76 minutes
(D) 152 minutes
(E) 190 minutes

Sample AP Free Response Question

$2\ NO(g) + 2\ H_2(g) \rightarrow N_2(g) + 2\ H_2O(g)$

Experiments conducted to study the rate of the reaction represented by the equation above. Initial concentrations and rates of reaction are given in the table below.

Experiment	Initial Concentration (mol/L) [NO]	[H_2]	Initial Rate of Formation of N_2 (mol/L min)
1	0.0060	0.0010	1.8×10^{-4}
2	0.0060	0.0020	3.6×10^{-4}
3	0.0010	0.0060	0.30×10^{-4}
4	0.0020	0.0060	1.2×10^{-4}

(a)

(i) Determine the order for each of the reactants, NO and H_2, from the data given and show your reasoning.
(ii) Write the overall rate law for the reaction.

(b) Calculate the value of the rate constant, k, for the reaction. Include units.
(c) For experiment 2, calculate the concentration of NO remaining when exactly one-half of the original amount of H_2 has been consumed.
(d) The following sequence of elementary steps is a proposed mechanism for the reaction.

I. $NO + NO \leftrightarrows N_2O_2$
II. $N_2O_2 + H_2 \rightarrow H_2O + N_2O$
III. $N_2O + H_2 \rightarrow N_2 + H_2O$

Based on the data present, which of the above is the rate-determining step? Show that the mechanism is consistent with:

(i) the observed rate law for the reaction, and
(ii) the overall stoichiometry of the reaction.

Answers:
17. D
23. B
49. B

Free Response: (1994 #2)
a) three points (point for each order must include justification)
From exps. 1 and 2: doubling [H_2] while keeping [NO] constant doubles the rate, therefore the reaction is first order in [H_2].
From exps. 3 and 4; doubling [NO] while keeping [H_2] constant quadruples the rate, therefore the reaction is second order in [NO].
Rate = $k\ [H_2]\ [NO]^2$
Note: full credit is earned for the rate expression as long as it is consistent with orders described by student.

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b) two points (one for value and one for units)
$k = \text{Rate} / ([H_2]\ [NO]^2)$
From exp. 1: $k = 1.8 \times 10^{-4}\ M/min\ /\ [(1.0 \times 10^{-3}\ M)\ (6.0 \times 10^{-3}\ M)^2]$
$= 5.0 \times 10^3\ M^{-2}\ min^{-1}$
Note: the unit is often written as $L^2\ mol^{-2}\ min^{-1}$

c) one point
Stoichiometry: NO : H_2 is 1:1
When 0.0010 mole of H_2 had reacted , it must have reacted with 0.0010 mole NO; thus [NO] remaining = 0.0060 - 0.0010 = 0.0050 M

d) three points
(i)
For I : $K_{eq} = [N_2O_2] / [NO]^2$
For II: Rate= $k[H_2] [N_2O_2]$
$[N_2O_2] = K_{eq} [NO]^2$
Rate = $k' [H_2][NO]^2$
Note: there must be some clear algebraic manipulation showing that $[N_2O_2]$ is proportional (NOT equal) to $[NO]^2$.
Step II is the rate determining step.
(ii)

I: $NO + NO \rightarrow N_2O_2$
II: $N_2O_2 + H_2 \rightarrow H_2O + N_2O$
III: $N_2O + H_2 \rightarrow N_2 + H_2O$
I + II + III: $2NO + 2H_2 \rightarrow N_2 + 2\ H_2O$