AP Chemistry Net-Ionic Equations

Things you need to know before you begin!

A. List of Polyatomic Ions.

Table of Common Polyatomic Ions

acetate (ethanoate)	CH_3COO^-	chromate	CrO_4^{2-}	phosphate	PO_4^{3-}
ammonium	NH_4^+	dichromate	$Cr_2O_7^{2-}$	hydrogen phosphate ion	HPO_4^{2-}
benzoate	$C_6H_5COO^-$	cyanide	CN^-	dihydrogen phosphate ion	$H_2PO_4^-$
borate	BO_3^{3-}	hydroxide	OH^-	silicate	SiO_3^{2-}
carbibe	C_2^{2-}	iodate	IO_3^-	sulfate	SO_4^{2-}
carbonate	CO_3^{2-}	nitrate	NO_3^-	hydrogen sulfate ion	HSO_4^-
hydrogen carbonate ion (bicarbonate ion)	HCO_3^-	nitrite	NO_2^-	sulfite	SO_3^{2-}
		oxalate	$OOCCOO^{2-}$	hydrogen sulfite ion	HSO_3^-
perchlorate	ClO_4^-	hydrogen oxalate ion	$HOOCCOO^-$	hydrogen sulfide ion	HS^-
chlorate	ClO_3^-	permangante	MnO_4^-	thiocyanate	SCN^-
chlorite	ClO_2^-	peroxide	O_2^{2-}	thiosulfate	$S_2O_3^{2-}$
hypochlorite	ClO^- or OCl^-	persulfide	S_2^{2-}		

B. Solubility Table.

Solubility of Some Common Ionic Compounds in Water at 298.15 K (25°C)

Ion	**H_3O^+ (H^+), Na^+, NH_4^+, NO_3^-, ClO_3^-, ClO_4^-, CH_3COO^-**	**F^-**	**Cl^- Br^- I^-**	**SO_4^{2-}**	**CO_3^{2-} PO_4^{3-} SO_3^{2-}**	**IO_3^- $OOCCOO^{2-}$**	**S^{2-}**	**OH^-**
Solubility greater than or equal to 0.1 mol/L (very soluble)	Most	most	most	most	NH_4^+ H^+ Na^+ K^+	NH_4^+ H^+ Li^+ Na^+ K^+ Ni^{2+} Zn^{2+}	NH_4^+ H^+ Li^+ Na^+ K^+ Mg^{2+} Ca^{2+}	NH_4^+ H^+ Li^+ Na^+ K^+ Ca^{2+} Sr^{2+} Ba^{2+}
Solubility less than 0.1 mol/L (slightly soluble)	$RbClO_4$ $CsClO_4$ $AgCH_3COO$ $Hg_2(CH_3COO)_2$	Li^+ Mg^{2+} Ca^{2+} Sr^{2+} Ba^{2+} Fe^{2+} Hg_2^{2+} Pb^{2+}	Cu^+ Ag^+ Hg_2^{2+} Hg^{2+} Pb^{2+}	Ca^{2+} Sr^{2+} Ba^{2+} Hg_2^{2+} Pb^{2+} Ag^+	most **Exception:** Li_2CO_3 is soluble	most **Exceptions:** $Co(IO_3)_2$ $Fe_2(OOCCOO)_3$ are soluble	most	Most

C. Strong Acids and Strong Bases

Strong Acids	Strong Bases
$HClO_{4\,(aq)}$	$NH_4OH_{\,(aq)}$
$HCl_{\,(aq)}$, $HBr_{\,(aq)}$, $HI_{\,(aq)}$	$LiOH_{\,(aq)}$; $NaOH_{\,(aq)}$; $KOH_{\,(aq)}$; $RbOH_{\,(aq)}$; $CsOH_{\,(aq)}$
$HNO_{3\,(aq)}$	$Ca(OH)_{2\,(aq)}$; $Sr(OH)_{2\,(aq)}$; $Ba(OH)_{2\,(aq)}$
$H_2SO_{4\,(aq)}$	

Note: You should also be familiar with all the weak acids and weak bases (especially weak bases that are polyatomic anions.

D. Complex Ions (Ligands; Metals, Lewis Base and Complex Ions Nomenclatures)

Metal Ions (Lewis Acids) and Coordination Numbers

Coordination Number (Ligands)	Metal Ions	Complex Ion Geometry
2	Cu^{+}, Ag^{+}, and Au^{+}	Linear
4	Cu^{+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Al^{3+} Cu^{2+}, Zn^{2+}, Hg^{2+}, Pt^{2+} and Au^{3+}	Tetrahedral or Square Planar
6	Mn^{2+}, Fe^{2+}, Fe^{3+}, Co^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Sc^{3+}, Cr^{3+}, Al^{3+} and Co^{3+}	Octahedral

Nomenclature for Metals in Complex Ions

Iron (Fe)	Ferrate	Lead (Pb)	Plumbate	Gold (Au)	Aurate
Copper (Cu)	Cuprate	Silver (Ag)	Argentate	Tin (Sn)	Stannate

Common Lewis Bases and Nomenclature in Complex Ions

Water (H_2O)	Aqua	Cyanide (CN^{-})	Cyano
Ammonia (NH_3)	Ammine	Thiocyanide (SCN^{-})	Thiocyano
Methylamine (CH_3NH_2)	Methylamine	Fluoride (F^{-})	Fluoro
Carbon Monoxide (CO)	Carbonyl	Chloride (Cl^{-})	Chloro
Nitrogen Monoxide (NO)	Nitrosyl	Bromide (Br^{-})	Bromo
Hydroxide (OH^{-})	Hydroxo	Iodide (I^{-})	Iodo

Nomenclature of Complexes Ions (see pg. 1001-1003 of textbook)

When naming a complex ion, first give the name(s) of the ligand(s), in alphabetical order, followed by the name of the metal.

Note the following:

- If a ligand is an anion whose name ends in -*ite* or -*ate*, the final *e* is changed to *o*. (example: change sulphat*e* to sulphat*o* and change nitrit*e* to nitrit*o*).
- If the ligand is an anion whose name ends in -*ide*, the ending is changed from -*ide* to -*o*. (example: change chlor*ide* to chlor*o* and cyan*ide* to cyan*o*).
- If the ligand is a neutral molecule, its common name is used. The important exceptions to this, however, are that water is called aqua, ammonia is called ammine, and CO is called carbonyl.
- When there is more than one of a particular ligand, the number of ligands is designated by the appropriate Greek prefix: di-, tri-, tetra-, penta-, hexa-, hepta-, etc.
- If the complex ion is an anion, the suffix -*ate* is added to the metal name. The Latin name is often used for the metal in this case. For example, ferro rather than iron and cupro rather than copper.
- Following the name of the metal, the oxidation number of the metal is given using Roman numerals.

Examples: $Fe(CN)_6^{3-}$ - hexacyanoferrate(III) $CoCl_4^{2-}$ - tetrachlorocobalte(II)
$Al(H_2O)_6^{3+}$ hexaaquaaluminum (III) $Ni(SCN)_6^{4-}$ - hexathiocyanonickelate (II)

E. Common Reducing and Oxidizing Agents that are not on the Table

Some Common Oxidizing and Reducing Agents

Oxidizing Agents	Reducing Agents
$MnO_4^- \rightarrow Mn^{2+}$ (acid / neutral); MnO_2 (basic)	Halide Ions → Elemental Halogens
$Cr_2O_7^{2-} \rightarrow Cr^{3+}$	Metal Elements → Metal Ions
$OOCCOO^{2-} \rightarrow CO_2$	$SO_3^{2-} \rightarrow SO_4^{2-}$
Halogen Elements → Halide ions	$NO_2^- \rightarrow NO_3^-$
$H_2O_2 \rightarrow H_2O$	Elemental Halogen → Halate / Hypohalite Ions (in basic solutions) (ClO_3^- or ClO^-)
$HNO_3 \rightarrow NO_2$ (concentrated); NO (dilute)	
H_2SO_4 (concentrated) → SO_2	

Species that can be BOTH Oxidizing and Reducing Agents

$SO_3^{2-} \rightarrow SO_4^{2-}$ or S

$S \rightarrow SO_3^{2-}$ or S^{2-}

F. Other "Little" Things – just in case they ask!

Some General Ions Colours in Solution for Row 1 of the Transition Metals

Ionic Species		Solution Concentrations	
		1.0 M	0.010 M
Dichromate	$Cr_2O_7^{2-}$	orange	pale orange
Chromate	CrO_4^{2-}	yellow	pale yellow
Chromium (III)	Cr^{3+}	blue-green	green
Cobalt (III)	Co^{3+}	yellow	pale yellow
Hexa-cyano-cobalt (III)	$Co(CN)_6^{3-}$	yellow	pale yellow
Hexa-ammine-cobalt (III)	$Co(NH_3)_6^{3+}$	yellow	pale yellow
Cobalt (II)	Co^{2+}	red	pink
Copper (II)	Cu^{2+}	blue	pale blue
Copper (I)	Cu^{+}	blue-green	pale blue-green
Iron (III)	Fe^{3+}	reddish-brown	pink
Tri-thiocyano-iron (III)	$Fe(SCN)_3$	red	pink
Hexa-cyano-iron (III)	$Fe(CN)_6^{3-}$	red	pink
Iron (II)	Fe^{2+}	lime green	colourless
Hexa-cyano-iron (II)	$Fe(CN)_6^{4-}$	yellow	pale yellow
Permanganate	MnO_4^-	deep purple	purple-pink
Manganese (IV)	Mn^{4+}	dark brown	reddish-brown
Manganese (II)	Mn^{2+}	pinkish-red	colourless
Nickel (II)	Ni^{2+}	green	pale green
Hexa-ammine-nickel (II)	$Ni(NH_3)_6^{2+}$	blue	pale blue
Vanadium (V)	V^{5+}	yellow	pale yellow
Vanadium (IV)	V^{4+}	blue	pale blue
Vanadium (III)	V^{3+}	blue-green	pale blue-green
Vanadium (II)	V^{2+}	violet	light purple

Flame Tests of Selected Cations

Pb^{2+} - light blue Hg^{+} - white Ag^{+} - gray Tl^{+} - green; Cu^{+} - blue green	Hg^{2+} - white Cu^{2+} - blue green Cd^{2+} - colourless As^{3+} - light blue Bi^{3+} - yellow brownish Sb^{3+} - green Sn^{4+} - colourless	Mn^{2+} - violet Fe^{2+} - yellow Fe^{3+} - brownish red Ni^{2+} - brown Co^{2+} - blue Zn^{2+} - whitish green Al^{3+} - colourless Cr^{3+} - green	Mg^{2+} - white Ca^{2+} - yellowish red Sr^{2+} - scarlet red Ba^{2+} - yellowish green	Li^{+} - red Na^{+} - yellow K^{+} - violet NH_4^{+} - green

Sample Net-Ionic Equation Questions

Answer Question 4 below. The Section II score weighting for this question is 10 percent.

4. For each of the following three reactions, in part (i) write a balanced equation and in part (ii) answer the question about the reaction. In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be graded.

EXAMPLE:

A strip of magnesium metal is added to a solution of silver(I) nitrate.

(i) Balanced equation:

$$Mg + 2\,Ag^{+} \longrightarrow Mg^{2+} + 2\,Ag$$

(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

Grading Net-Ionic Equations

There are three net-ionic equation questions. Each question is worth 5 points. The points are usually allotted as follows:

- 1 or 2 points for the correct reactant(s)
- 1 or 2 points for the correct product(s)
- 1 point for the correct balancing
- 1 point for the correct answer to part (ii)

Note: Phases do not need to be indicated (no penalty if present but incorrect). Any spectator ions on the reactant side nullify the one possible reactant point, but if they appear again on the product side, there is no product-point penalty. A fully molecular equation (when it should be ionic) that is correctly balanced earns a maximum of two points in part (i). Ion charges must be correct.

Reaction Types

1. Composition Reactions

Element + Element → Compound (Formation Reaction)

Metal Oxide + Non-metal Oxide → Polyatomic-Ion(s) Compound

a. i. Potassium metal is reacted with excess fluorine gas.
ii. Besides composition (formation) reaction, what type of reaction could this be classified as?

$2\ K + Cl_2 \rightarrow 2\ KCl$
Reduction and Oxidation – there are changes in oxidation numbers (For K: from 0 to +1 and for Cl: from 0 to –1)

b. i. Excess carbon dioxide gas is passed over hot, potassium oxide solid.
ii. What will be the resulting color when the product is dissolved in water containing bromothymol blue?

$K_2O + CO_2 \rightarrow K_2CO_3$
Blue – the product is a base as $K_2CO_3 \rightarrow 2\ K^+ + CO_3^{2-}$ (Bronsted – Lowry Base)

2. Decomposition Reactions

Compound $\xrightarrow{heat\ or\ catalyst}$ Element + Element (Deformation Reaction)

Polyatomic-Ion(s) Compound $\xrightarrow{heat}$ Metal Oxide (if there are metals) + Non-metal Oxide

a. i. Hydrogen Peroxide is decomposed catalytically.
ii. Name a catalyst that would work for the above reaction.

$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$
MnO_2, Ag, Pt

b. i. Solid ammonium sulfite is heated.
ii. Classified the type of reaction.

$(NH_4)_2SO_3 \rightarrow 2\ NH_3 + SO_2 + H_2O$
Decomposition, Redox

3. Single Replacement Reactions

Element + Compound → Different Element + Different Compound (Can be Redox)

a. i. Chlorine gas is bubbled through a solution of sodium bromide.
ii. What is the reducing agent in this reaction?

$Cl_2 + 2\ Br^- \rightarrow 2\ Cl^- + Br_2$
Br^- is the reducing agent (oxidation number increases from –1 to 0)

b. i. A piece of copper metal is placed in a 1 M silver (I) nitrate solution.
ii. Describe two observations from the above reaction.

$Cu + 2\ Ag^+ \rightarrow Cu^{2+} + 2\ Ag$
The solution will turn blue (or light blue) because of the increase $[Cu^{2+}]$ and solid silver (crystal) will precipitate (or the copper metal is being corroded away).

4. Double Replacement Reaction

Ionic Compound + Ionic Compound → Different Ionic Compound + Different Ionic Compound

a. i. A 0.300 L of 1.00 M calcium nitrate solution is mixed with an equal volume of 1.00 M of potassium phosphate solution.
ii. How many moles of the precipitate are expected from this reaction?

$3\ Ca^{2+} + 2\ PO_4^{3-} \rightarrow Ca_3(PO_4)_2$
0.100 mole of precipitate

5. Combustion Reaction

Metal + Oxygen → Metal Oxide **(Formation Reaction)**
Non-Metal + Oxygen → Non-Metal Oxide **(Formation Reaction)**
Hydrocarbon + Oxygen → CO_2 + H_2O **(Hydrocarbon Combustion)**
Ionic Compound + Oxygen → Metal Oxide + Non-Metal Oxide

a. i. Sucrose is consumed through the process of cellular respiration.
ii. Classify the type of the above reaction.

$C_{12}H_{22}O_{11} + 12\ O_2 \rightarrow 12\ CO_2 + 11\ H_2O$
(Hydrocarbon) Combustion

b. i. Solid iron (II) sulfide is burned completely.
ii. Determine the substance undergoing reduction.

$4\ FeS + 7\ O_2 \rightarrow 2\ Fe_2O_3 + 4\ SO_2$
Oxygen is reduced (oxidation number decrease from 0 to –2)

c. i. Common sulfur is ignited outdoor.
ii. What is the geometrical shape of the resulting molecule?

$S_8 + 16\ O_2 \rightarrow 8\ SO_2$
V-Shape or Bent (10 electrons – dsp^3 hybridzation)

6. Acid-Base Neutralizations
(Do NOT break up Weak Acids or Weak Bases; ALWAYS break up Strong Acids and Strong Base)

a. i. A 25 mL of 0.1 M of nitrous acid is added to 25 mL of 0.1 M of sodium hydroxide solution.
ii. Will the resulting solution has a pH greater than, less than or equal to 7? Explain.

$HNO_2 + OH^- \rightarrow H_2O + NO_2^-$
The pH will be greater than 7 since NO_2^- is a weak base.

b. i. A given volume 0.1 M sodium phosphate solution is poured into three times the volume of 0.1 M hydrochloric acid.
ii. Identify the ion(s) with the highest concentration at the first equivalence point.

$PO_4^{3-} + 3\ H^+ \rightarrow H_3PO_4$ or $PO_4^{3-} + 3\ H_3O^+ \rightarrow H_3PO_4 + 3\ H_2O$
HPO_4^- will have the high concentration at the first equivalence point.

c. i. Ammonium sulfite solution is added to a saturated solution of calcium hydroxide.
ii. What is the precipitate of this reaction?

$2\ NH_4^+ + SO_3^{2-} + Ca^{2+} + 2\ OH^- \rightarrow 2\ NH_3 + 2\ H_2O + CaSO_3$
$CaSO_3$ is the precipitate

7. Additions with Water

Metal + Water → Metal Hydroxide + H_2

Non-Metal + Water → Usually No Reaction (except Cl_2 – will explain in Redox)

Metal Hydride + Water → Metal Hydroxide + H_2

Metal Oxide + Water → Metal Hydroxide (Base)

Non-Metal Oxide + Water → Acid (Strong or Weak)

(Special reactions – $N_2O_3 + H_2O \rightarrow 2\ HNO_2$; $N_2O_5 + H_2O \rightarrow 2\ H^+ + 2\ NO_3^-$)

a. i. A 0.1 mol potassium metal is dropped into 1 L water.
ii. What is the pH of the resulting solution?

$K + H_2O \rightarrow K^+ + OH^- + H_2$
pH = 13

b. i. Solid barium oxide is added to water.
ii. A few drop of phenolphthalein was in the water, what is the resulting color of the solution?

$BaO + H_2O \rightarrow Ba^{2+} + 2\ OH^-$
Pink (Basic Solution)

c. i. Sulfur dioxide gas is bubbled into water.
ii. Identify the Lewis acid and base of the above equation.

$SO_2 + H_2O \rightarrow H_2SO_3$ (weak acid – do not break up)
SO_2 is the Lewis Acid; H_2O is the Lewis Base

d. i. A piece sodium hydride is dropped into water.
ii. What is the color of the flame test when it is used on the products?

$NaH + H_2O \rightarrow Na^+ + OH^- + H_2$
Because of the presence of sodium ion, the color of the flame test should be yellow.

8. Complex-Ion Reactions
(Know the Nomenclature and Ligands. Watch for Lewis Acids and Bases)

a. i. Excess ammonia solution is added to solid silver chloride.
ii. How will the solubility of silver chloride be affected if concentrated hydrochloric acid is added to the final solution? Explain

$AgCl + 2\ NH_3 \rightarrow Ag(NH_3)_2^+$
The solubility of silver chloride would decrease because of Le Chatelier Principle. As an acid is added to the system, it would decrease the ammonia (base) concentration. This would result in shifting the equilibrium to the left and precipitating more AgCl.

b. i. Excess amount of sodium hydroxide is added to a chromium (III) nitrate solution.
ii. What is the name of the final product of this reaction?

$Cr^{3+} + 6\ OH^- \rightarrow Cr(OH)_6^{3-}$
Hexahydroxochrominate (III) ion

c. i. A small amount of sodium thiocyanate solution is added to iron (III) chloride solution.
ii. Draw the two possible Lewis diagrams for thiocyanate.

$Fe^{3+} + SCN^- \rightarrow FeSCN^{2+}$ or $Fe^{3+} + 5\ H_2O + SCN^- \rightarrow Fe(H_2O)_5SCN^{2+}$

$[\ S–C{\equiv}N\ ]^-$ and $[\ S{=}C{=}N\ ]^-$

9. Redox Reactions

(List all species. Identify Strongest Oxidizing Agent - SOA and Strongest Reducing Agent - SRA. Balance reduction and oxidation half-reactions separately before combining.)

a. i. A 1 M acidified potassium dichromate solution is reacted with 1 M of tin (II) chloride solution
ii. What is the oxidation number of chromium in dichromate ion?

$Cr_2O_7^{2-} + 14\ H^+ + 3\ Sn^{2+} \rightarrow 2\ Cr^{3+} + 7\ H_2O + 3\ Sn^{4+}$
Cr has an oxidation number of +6 in $Cr_2O_7^{2-}$.

b. i. A solution of sodium iodide is electrolyzed.
ii. What products are collected in the two electrodes?

$2\ I^- + 2\ H_2O \rightarrow H_2 + 2\ OH^- + I_2$
The iodine solid is collected at the anode – positive terminal (oxidation). The hydrogen gas will be bubbling out at the cathode – negative electrode (reduction).

c. i. Chlorine gas is bubbled through water. (unlikely question)
ii. What are the oxidizing and reducing agents in this reaction?

$Cl_2 + H_2O \rightarrow H^+ + Cl^- + HClO$
Chlorine gas is both the oxidizing and reducing agent.
(Reduction: $Cl_2 \rightarrow Cl^-$ and Oxidation: $Cl_2 \rightarrow HClO$)

10. Organic Reactions (*It would be a good idea to briefly go through your Organic Nomenclature!)*

(Additions) Alkene / Alkyne Hydrocarbons + Halogens / Hydrohalides → Haloalkanes / Haloalkenes
Alkene Hydrocarbons + Water → Alcohols

a. i. An equal amount of ethyne is reacted with hydrogen bromide with a catalyst.
ii. What is the hybridization of the carbon-carbon bond in the final product?

$C_2H_2 + HBr \rightarrow C_2H_3Br$
The resulting product has a double bond. Hence it has a sp^2 hybridization.

(Substitutions) Alkane Hydrocarbons (or Benzene) + Halogen $\xrightarrow{h\nu}$ Haloalkane + Hydrogen Halide

b. i. Propane gas and chlorine gas are reacted under UV light.
ii. Give the names of both isomers in this reaction.

$C_3H_8 + Cl_2 \xrightarrow{h\nu} C_3H_7Cl + HCl$
1-chloropropane and 2-chloropropane

(Esterifications) Carboxylic Acids + Alcohols $\xrightarrow{H_2SO_4}$ Esters + Water

c. i. Propanoic Acid is added to ethanol with a few drop of concentrated sulfuric acid.
ii. Give the IUPAC name of the product.

$C_2H_5COOH + C_2H_5OH \xrightarrow{H_2SO_4} C_2H_5COOC_2H_5 + H_2O$
Ethylpropanoate