Name: KEY

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Chemistry 30
Electrochemistry Workbook

Net Ionic Equations

For each of the following reactions, write and label the half reactions and the net ionic equation. (2 marks each)

1. $Fe(s) + Cu(NO_3)_2(aq) \rightarrow Cu(s) + Fe(NO_3)_2(aq)$

   $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

   $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

   $Fe(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Fe^{2+}(aq)$

2. $2\ Al(CH_3COO)_3(aq) + 3\ Sn(s) \rightarrow 3\ Sn(CH_3COO)_2(aq) + 2\ Al(s)$

   $(Al^{3+}(aq) + 3e^- \rightarrow Al(s)) \times 2$

   $(Sn(s) \rightarrow Sn^{2+}(aq) + 2e^-) \times 3$

   $2Al^{3+}(aq) + 3Sn(s) \rightarrow 2Al(s) + 3Sn^{2+}(aq)$

3. $Cl_2(g) + CaI_2(aq) \rightarrow I_2(s) + CaCl_2(aq)$

   $Cl_2(g) + 2e^- \rightarrow 2Cl^{1-}(aq)$

   $2I^{1-}(aq) \rightarrow I_2(s) + 2e^-$

   $Cl_2(g) + 2I^{1-}(aq) \rightarrow 2Cl^{1-}(aq) + I_2(s)$

Predicting Redox Reactions

For each of the following situations, determine the net redox reaction and state the spontaneity: (3marks each)

1. Aqueous solutions of tin (II) bromide and iron (III) nitrate are mixed.

   $Sn^{2+}(aq)$ (RA), $Br^{1-}(aq)$, $Fe^{3+}(aq)$ (OA), $NO_3^{1-}(aq)$, $H_2O(l)$

   $Fe^{3+}(aq) + 1e^- \rightarrow Fe^{2+}(s)$

   $Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$

   $2Fe^{3+}(aq) + Sn^{2+}(aq) \rightarrow 2Fe^{2+}(aq) + Sn^{4+}(aq)$ spontaneous

2. A laboratory technician stores an aqueous solution of iron (III) chloride in a nickel plated container. $Fe^{3+}(aq)$ (SOA) $Cl^{1-}(aq)$ (RA) $Ni(s)$ (SRA) $H_2O(l)$

   $Fe^{3+}(aq) + 1e^- \rightarrow Fe^{2+}(aq)$

   $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$

   $2Fe^{3+}(aq) + Ni(s) \rightarrow 2Fe^{2+}(aq) + Ni^{2+}(aq)$ spontaneous

3. A chemistry teacher demonstrates the test for bromide ions by bubbling some chlorine gas cautiously through a sodium bromide solution.

   $Cl_2(g)$ (SOA) $Na^{1+}(aq)$, $Br^{1-}(aq)$ (SRA), $H_2O(l)$

   $Cl_2(g) + 2e^- \rightarrow 2Cl^{1-}(aq)$

   $2Br^{1-}(aq) \rightarrow Br_2(l) + 2e^-$

   $Cl_2(g) + 2Br^{1-}(aq) \rightarrow 2Cl^{1-}(aq) + Br_2(l)$ spontaneous

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$H^+(aq)$ $K^+(aq)$ $Cr_2O_7^{2-}(aq)$ $Sn^{2+}(aq)$ $SO_4^{2-}(aq)$

4. Acidified potassium dichromate is added to a solution of tin(II) sulphate.

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

$(\times 3)\ Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2e^-$

Spontaneous $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 3Sn^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3Sn^{4+}(aq)$

5. A solution of nickel(II) nitrate is stored in a copper container.

$Ni^{2+}(aq)$ (SOA), $NO_3^{1-}(aq)$, $Cu(s)$ (SRA), $H_2O(l)$

$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$

$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

$Ni^{2+}(aq) + Cu(s) \rightarrow Ni(s) + Cu^{2+}(aq)$ *nonspontaneous

6. Two students attempt to etch their initials on a copper plate using hydrochloric acid.

$Cu(s)$ (SRA), $H^+(aq)$ (SOA), $Cl^{1-}(aq)$, $H_2O(l)$

$2H^+(aq) + 2e^- \rightarrow H_2(g)$

$Cu(s) \rightarrow Cu^{2+} + 2e^-$

$2H^+(aq) + Cu(s) \rightarrow H_2(g) + Cu^{2+}(aq)$ *nonspontaneous

7. An iron bolt is exposed to air and water, a reaction which causes millions of dollars of damage each year.

$Fe(s)$ (SRA) $O_2(g)$ $H_2O(l)$ (SOA)

$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^{1-}(aq)$

$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

$O_2(g) + 2H_2O(l) + 2Fe(s) \rightarrow 4OH^{1-}(aq) + 2Fe^{2+}(aq)$ spontaneous

Generating Redox Tables

Use the following information to answer the next question.

In a laboratory, a student obtained the following results when testing, under standard conditions, reactions between various metals and their corresponding ions.

RA →

OA ↓

	W(s)	X(s)	Y(s)	Z(s)
W^{3+}(aq)	–	×	✓	✓
X^{2+}(aq)	✓	–	✓	✓
Y^{2+}(aq)	×	×	–	✓
Z^{2+}(aq)	×	×	×	–

× denotes no reaction
✓ denotes a reaction
– denotes not tested

1. **Generate a table** of relative strengths of oxidizing and reducing agents for the metals and metal ions in the data chart. Write all half-reaction equations as reductions and label the strongest oxidizing agent and the strongest reducing agent. (3marks)

SOA $X^{2+}(aq) + 2e^- \rightarrow X(s)$

$W^{3+}(aq) + 3e^- \rightarrow W(s)$

$Y^{2+}(aq) + 2e^- \rightarrow Y(s)$

$Z^{2+}(aq) + 2e^- \rightarrow Z(s)$ SRA

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2. In an experiment, four metals were placed into test tubes containing various ion solutions. Their resulting behaviour is communicated by the equations below. **List the oxidizing agents** from strongest to weakest. (3 marks)

$$Pt(s) + 2\,H^+(aq) \xrightarrow{\text{nonspont}} Pt^{2+}(aq) + H_2(g)$$

$$2\,Ce(s) + 3\,Ni^{2+}(aq) \xrightarrow{\text{spont}} 2\,Ce^{3+}(aq) + 3\,Ni(s)$$

$$3\,Sr(s) + 2\,Ce^{3+}(aq) \xrightarrow{\text{spont}} 3\,Sr^{2+}(aq) + 2\,Ce(s)$$

$$Ni(s) + 2\,H^+(aq) \xrightarrow{\text{spont}} Ni^{2+}(aq) + H_2(g)$$

$Pt^{2+}(aq) + 2e^- \rightarrow Pt$

$2H^+(aq) + 2e^- \rightarrow H_2(g)$

$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$

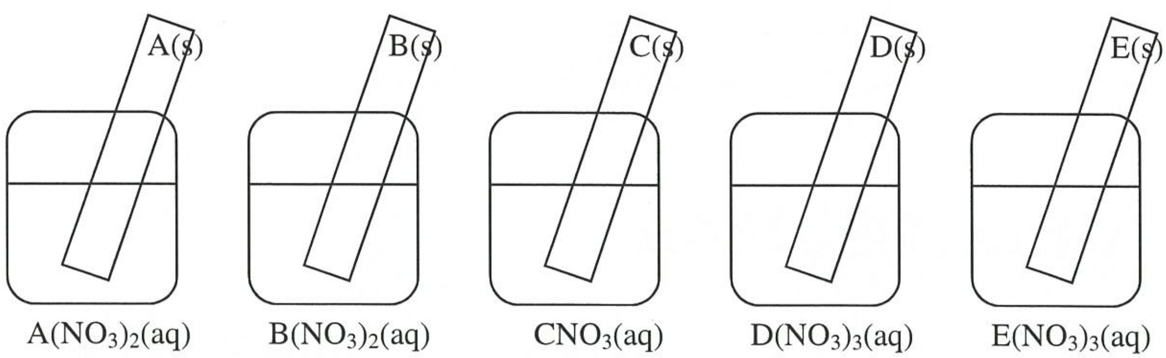
$Ce^{3+}(aq) + 3e^- \rightarrow Ce$

$Sr^{2+}(aq) + 2e^- \rightarrow Sr$

$Pt^{2+}(aq)$, $2H^+(aq)$, $Ni^{2+}(aq)$, $Ce^{3+}(aq)$, $Sr^{2+}(aq)$

Use the following information to answer the next question.

Metals and Metal Nitrates



C(s) in all solutions – no reactions

D(s) in only $E(NO_3)_3(aq)$ and $A(NO_3)_2(aq)$ – reaction and no reaction respectively

B(s) in all solutions – no reaction with $A(NO_3)_2(aq)$

3. Given the list of observations above, **list the reducing agents** from most reactive to least reactive. (3marks)

$C^+(aq) + 1e \rightarrow C$

E^{3+} E

D^{3+} D

B

A^+ A

A(s), B(s), D(s), E(s), C(s)

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Oxidation Numbers

1. Determine the oxidation number for **carbon** in each of the following substances: (2 marks)

   a) $\overset{+4}{C}O_2$ b) $\overset{0}{C}_{12}H_{22}O_{11}$ (+1 −2) c) $\overset{+4}{C}O_3^{2-}$ d) $H\overset{+4}{C}O_3^-$ (+1 −6)

2. Determine the oxidation number of the element in ***bold*** type in each of the following compounds or polyatomic ions: (4 marks)

   a) $\boldsymbol{C}_2H_6O$ −2 (+6 −2) b) $\boldsymbol{Os}O_4$ +8 c) $K_2\boldsymbol{Ta}F_7^{2-}$ +5 (+5 −7) d) $\boldsymbol{U}O_2$ +4

   e) $Na_2\boldsymbol{Cr}_3O_{10}^{2-}$ +6 (−20) f) $\boldsymbol{As}_2S_5$ +5 (−2) g) $\boldsymbol{S}_2O_3$ +3 h) $\boldsymbol{S}_4O_6$ +3

3. For each of the following reactions, determine whether the element in ***bold*** type has been oxidized or reduced: (3marks)

   a) $\overset{0}{\boldsymbol{Mg}}(s) + Fe_2O_3(s) \rightarrow Fe(s) + \overset{+2}{\boldsymbol{Mg}}O(s)$ oxidized

   b) $Na_2\overset{+4}{\boldsymbol{C}}O_3(s) \rightarrow Na_2O(s) + \overset{+4}{C}O_2(g)$ neither

   c) $\overset{-2}{\boldsymbol{C}}_2H_5OH(l) + O_2(g) \rightarrow \overset{+4}{C}O_2(g) + H_2O(g)$ oxidized (+6 −2)

Balancing Redox Half Reactions

Balance the following half reactions: (1 mark each)

1. $10e^- + 12H^+(aq) + 2IO_3^-(aq) \rightarrow I_2(s) + 6H_2O(l)$

2. $2e^- + S_2O_8^{2-}(aq) \rightarrow 2SO_4^{2-}(aq)$

3. $2e^- + 2H^+(aq) + Cl_2O^{2-}(aq) \rightarrow 2Cl^-(aq) + H_2O(l)$

4. $2H_2O(l) + AsO_2(s) \rightarrow AsO_4^{3-}(aq) + 4H^+(aq) + 1e^-$

5. $H_2O(l) + SO_3^{2-}(aq) \rightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$

6. $6e^- + 6H^+(aq) + IO_3^-(aq) \rightarrow I^-(aq) + 3H_2O(l)$

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Balancing Redox Reactions – Half Reaction Method

Complete and balance the following redox reactions using the half-reaction method. Include the net ionic equation in its simplified form. (2 marks each)

1. $H_2C_2O_4(aq) + MnO_4^-(aq) \rightarrow Mn^{2+}(aq) + CO_2(g)$

(x5) $H_2C_2O_4(aq) \rightarrow 2CO_2(g) + 2H^+(aq) + 2e^-$

(x2) $5e^- + 8H^+(aq) + MnO_4^{1-}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

$5H_2C_2O_4(aq) + 6H^+(aq) + 2MnO_4^{1-}(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$

2. $AsO_3^{3-}(aq) + BrO_3^-(aq) \rightarrow Br^-(aq) + AsO_4^{3-}(aq)$

$H_2O + AsO_3^{3-} \rightarrow AsO_4^{3-} + 2H^+ + 2e^-$

$6e^- + 6H^+ + BrO_3^- \rightarrow Br^- + 3H_2O$

$3AsO_3^{3-}(aq) + BrO_3^{1-}(aq) \rightarrow 3AsO_4^{3-}(aq) + Br^{1-}(aq)$

3. $NH_3(aq) + Cu^{2+}(aq) \rightarrow NO_3^-(aq) + Cu^+(aq)$

$3H_2O(l) + NH_3(aq) \rightarrow NO_3^{1-}(aq) + 9H^+(aq) + 8e^-$

$Cu^{2+} + 1e \rightarrow Cu^+$

$3H_2O(l) + NH_3(aq) + 8Cu^{2+}(aq) \rightarrow NO_3^{1-}(aq) + 9H^+(aq) + 8Cu^+(aq)$

4. $Cr_2O_7^{2-}(aq) + Sn^{2+}(aq) \rightarrow Cr^{3+}(aq) + Sn^{4+}(aq) + H_2O(l)$

$14H^+ + Cr_2O_7^{2-}(aq) + 6e^- \rightarrow 2Cr^{3+} + 7H_2O(l)$

$Sn^{2+} \rightarrow Sn^{4+} + 2e^-$

$14H^+(aq) + Cr_2O_7^{2-}(aq) + 3Sn^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3Sn^{4+}(aq)$

Balancing Redox Reactions – Oxidation Number Method

Complete and balance the following redox reactions using the oxidation number method. Please use the lowest whole number ratio. (2 marks each)

1. 8 $H^+(aq)$ + 3 $S^{2-}(aq)$ + 2 $NO_3^-(aq)$ → 3 $S(s)$ + 2 $NO(g)$ + 4 $H_2O(l)$

(-2, +5, 0, +2; $2e/S^{2-}$, $3e^-/NO_3^-$)

2. 6 $H^+(aq)$ + 2 $MoO_3(s)$ + 3 $Zn(s)$ → ___ $Mo_2O_3(s)$ + 3 $Zn^{2+}(aq)$ + 3 $H_2O(l)$

(+6, 0, +3, +2; $3e^-/MoO_3$, $2e^-/Zn$)

3. 7 $H_2O(l)$ + 8 $Al(s)$ + 3 $NO_3^-(aq)$ → 8 $AlO_2^-(aq)$ + 3 $NH_3(aq)$ + 5 $H^+(aq)$

(0, +5, +3, -3; $3e/Al$, $8e/NO_3$)

4. 12 $H^+(aq)$ + 3 $ClO_2^-(aq)$ + 4 $Fe(s)$ → 4 $Fe^{3+}(aq)$ + 3 $Cl^-(aq)$ + 6 $H_2O(l)$

(+3, 0, +3, -1; $4e/ClO_2^-$, $3e/Fe$)

Redox Stoichiometry

1. A 2.75 g piece of aluminum is placed in 250 mL of iron(III) nitrate solution. Assuming that the reaction reaches endpoint, calculate the concentration of the $Fe^{3+}(aq)$ ions. (3 marks)

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$

$Al(s) \rightarrow Al^{3+}(aq) + 3e^-$

$3Fe^{3+}(aq) + Al(s) \rightarrow 3Fe^{2+}(aq) + Al^{3+}(aq)$

V=250 mL, 2.75 g, C=?

① moles Al(s): $\frac{26.98g}{1 mol} = \frac{2.75g}{x mol}$, x = 0.1019 mol

② $\frac{3 mol Fe^{3+}(aq)}{1 mol Al} = \frac{x mol}{0.1019...}$, x = 0.30578 mol

④ $C = \frac{n}{V} = \frac{0.30578}{0.250} = 1.22 mol/L$

2. If 6.00 mol/L nitric acid is poured into a beaker containing 50.0 mL of 1.50 mol/L hydrogen peroxide, what volume of acid is needed to reach endpoint? (3 marks)

$H_2O_2(l) \rightarrow O_2(g) + 2H^+(aq) + 2e^-$

$2NO_3^-(aq) + 4H^+(aq) + 2e^- \rightarrow N_2O_4(g) + 2H_2O(l)$

$H_2O_2(l) + 2NO_3^{1-}(aq) + 2H^+(aq) \rightarrow O_2(g) + N_2O_4(g) + 2H_2O(l)$

V=0.050 L, C=1.50 mol/L; C=6.00 mol/L

25.0 mL

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① $\frac{1.50 mol}{1 L} = \frac{x mol}{0.050}$ ② $\frac{0.075 mol H_2O_2}{x mol NO_3^{1-}} = \frac{1 mol H_2O_2}{2 mol NO_3^{1-}}$ ③ $\frac{0.15 mol}{x} = \frac{6.00 m}{1 L}$

3 marks

3. If 30.0 mL of acidic dichromate ion solution is poured into a beaker containing 50.0 mL of 0.400 mol/L tin(II) nitrate, calculate the dichromate ion concentration and the $Sn^{4+}(aq)$ concentration.

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 3Sn^{2+}(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 3Sn^{4+}(aq)$

V = 30.0 mL; V = 50.0 mL, C = 0.400 mol/L

① mole $Sn^{2+}(aq)$: 0.0200 mol
② mol $Cr_2O_7^{2-}(aq)$: 0.00666 mol
③ Conc. $Cr_2O_7^{2-}$: 0.222 mol/L
Conc. $Sn^{4+}(aq)$: $\frac{0.0200}{0.080}$ = 0.250 — 0.250 mol/L

3marks

4. In an experiment to analyze the iron in an iron ore sample, 0.05000 mol/L $K_2Cr_2O_7(aq)$ was used in an acidic solution to oxidize $Fe^{2+}(aq)$ ions to $Fe^{3+}(aq)$ ions. Use the following data to calculate the concentration of $Fe^{2+}(aq)$ in the solution:

volume of $Fe^{2+}(aq)$ solution..............................25.0 mL
final buret reading ($K_2Cr_2O_7(aq)$).......................48.7 mL
initial buret reading.......................................3.7 mL

45 mL $Cr_2O_7^{2-}$

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6Fe^{2+}(aq) \rightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$

0.05000 mol/L, 45 mL; 25 mL, n = 0.0135 mol

0.00225 mol

0.54 mol/L

3marks

5. Another experiment was used to analyze the tin in a tin ore sample. The $Sn^{2+}(aq)$ ions in an acidic solution were oxidized to $Sn^{4+}(aq)$ by a 0.200 mol/L $KMnO_4(aq)$ solution. Use the following information to calculate the concentration of $Sn^{2+}(aq)$ in the solution.

volume of $Sn^{2+}(aq)$ solution..............................10.0 mL
final buret reading ($KMnO_4(aq)$)..........................39.3 mL
initial buret reading.......................................1.8 mL

37.5 mL

$2MnO_4^-(aq) + 16H^+(aq) + 5Sn^{2+}(aq) \rightarrow 2Mn^{2+} + 8H_2O(l) + 5Sn^{4+}(aq)$

0.200 mol/L, 37.5 mL; V = 10.0 mL, C = ?

n = 0.0075 mol

$\frac{2 \text{ mol } MnO_4^-}{5 \text{ mol } Sn^{2+}} = \frac{0.0075 \text{ mol}}{x\ Sn^{2+}}$

x = 0.01875 mol

$C = \frac{0.01875}{0.010}$

1.875 mol/L

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