LAB EXERCISE 9.1.1 OXIDATION STATES OF VANADIUM

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Analysis

(a) (1) $VO^{-}_{3(aq)}$ (vanadate(V) ion from the dissociation of ammonium vanadate(V))

(2) $VO^{-}_{3(aq)} \rightarrow VO^{2+}_{(aq)} \rightarrow V^{3+}_{(aq)} \rightarrow V^{2+}_{(aq)}$

(3) $V^{2+}_{(aq)} \rightarrow V^{3+}_{(aq)}$

(4) $VO^{-}_{3(aq)} \rightarrow VO^{2+}_{(aq)}$ (**Note:** $VO^{2+}_{(aq)}$ is not reduced further by KI as indicated in (5).)

(5) $VO^{2+}_{(aq)}$ (no change)

(6) $V^{2+}_{(aq)} \rightarrow V^{3+}_{(aq)} \rightarrow VO^{2+}_{(aq)} \rightarrow VO^{-}_{3(aq)}$

(b) (1) no reaction

(2) vanadium is being reduced from +5 to +4 to +3 to +2

(3) vanadium is being oxidized from +2 to +3

(4) vanadium is being reduced from +5 to +4

(5) no change in oxidation number

(6) vanadium is being oxidized from +2 to +3 to +4 to +5

(c) (3) The $V^{2+}_{(aq)}$ is slowly changed to $V^{3+}_{(aq)}$. This is an oxidation probably caused by the reaction of oxygen in the air with $V^{2+}_{(aq)}$.

(4) The $VO^{-}_{3(aq)}$ is likely reduced to $VO^{2+}_{(aq)}$, which is blue. At the same time, iodide ions are likely being oxidized to iodine, which is yellow-brown in aqueous solution. The combination of blue and yellow-brown would produce a very dark coloured mixture.

(5) Iodide ions are not able to reduce $VO^{2+}_{(aq)}$.

(6) Permanganate ions are able to successively oxidize $V^{2+}_{(aq)}$ to $V^{3+}_{(aq)}$ to $VO^{2+}_{(aq)}$ and finally, to $VO^{-}_{3(aq)}$.

(d) This equilibrium does not alter the analysis based on oxidation numbers. The oxidation number for vanadium in both $VO^{-}_{3(aq)}$ and $VO^{+}_{2(aq)}$ is +5.

INVESTIGATION 9.3.1 SPONTANEITY OF REDOX REACTIONS

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Prediction

(a) Based on previous assumptions for chemical reactions and stoichiometry, all combinations that result in products different from reactants are spontaneous. Therefore, all metals should react with compounds of other metal ions.

Procedure

(b) 1. Clean one side of each of the four metal strips, using steel wool.

2. Add 1 drop of $Cu(NO_3)_{2(aq)}$ on each of the four metals.

3. Repeat step 2, using $Pb(NO_3)_{2(aq)}$, $AgNO_{3(aq)}$, and $Zn(NO_3)_{2(aq)}$ on different parts of the metal strips.

4. Rinse the lead and silver solutions into a labelled waste container and clean the metal strips for reuse.

Evidence

(c) **Reactions of Metals and Their Ions**

	$Cu_{(s)}$	$Pb_{(s)}$	$Ag_{(s)}$	$Zn_{(s)}$
$Cu^{2+}_{(aq)}$	slightly cleaner metal surface	red-brown precipitate	no change	red-brown precipitate
$Pb^{2+}_{(aq)}$	no change	no change	no change	black precipitate
$Ag^{+}_{(aq)}$	silver crystals	silver crystals	no change	silver crystals
$Zn^{2+}_{(aq)}$	no change	no change	no change	no change

Analysis

(d) The evidence obtained is consistent with spontaneous, single displacement reactions for only the combinations of:
- copper metal and silver ions;
- lead metal and copper(II) ions;
- lead metal and silver ions; and
- zinc metal and each of copper(II), silver, and lead(II) ions.

Evaluation

(e) The experimental design was adequate to answer the problem since only evidence for a reaction (not the identity of the product) was required. The materials and procedure were adequate, although the short observation time did create a little uncertainty for those combinations that did not appear to react.

(f) Two aspects of this experiment could be improved. The combinations that did not appear to react could be left longer in case there was a slow reaction. Some diagnostic tests could be done to determine the identity of any products produced.

(g) Overall, the prediction is judged to be falsified since six out of the twelve predicted spontaneous reactions did not give any evidence of a chemical change. The mixture of a metal and a solution of its own ion was predicted to be nonspontaneous and this was verified with the possible exception of the copper system, which would require further testing.

(h) The assumption of spontaneous reactions is judged to be unacceptable since the prediction was clearly falsified. The assumption will need to be restricted, revised, or discarded.

LAB EXERCISE 9.3.1 BUILDING A REDOX TABLE

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Analysis

(a) SOA $Br_{2(aq)} + 2\,e^- \rightleftharpoons 2\,Br^-_{(aq)}$

$Ag^+_{(aq)} + e^- \rightleftharpoons Ag_{(s)}$

$I_{2(aq)} + 2\,e^- \rightleftharpoons 2\,I^-_{(aq)}$

$Cu^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Cu_{(s)}$ SRA

Synthesis

(b) SOA $Cl_{2(aq)} + 2\,e^- \rightleftharpoons 2\,Cl^-_{(aq)}$

$Br_{2(aq)} + 2\,e^- \rightleftharpoons 2\,Br^-_{(aq)}$

$Ag^+_{(aq)} + e^- \rightleftharpoons Ag_{(s)}$

$I_{2(aq)} + 2\,e^- \rightleftharpoons 2\,I^-_{(aq)}$

$Cu^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Cu_{(s)}$

$Pb^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Pb_{(s)}$

$Zn^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Zn_{(s)}$ SRA

INVESTIGATION 9.3.2 THE REACTION OF SODIUM WITH WATER

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Prediction

(a) According to the method for predicting redox reactions, the products of the reaction are hydrogen gas and aqueous sodium hydroxide as shown below.

	SOA
$Na_{(s)}$	$H_2O_{(l)}$
SRA	RA

$$2\,H_2O_{(l)} + 2\,e^- \rightarrow H_{2(g)} + 2\,OH^-_{(aq)}$$

$$2\,[Na_{(s)} \rightarrow Na^+_{(aq)} + e^-]$$

$$2\,H_2O_{(l)} + 2\,Na_{(s)} \xrightarrow{\text{spont.}} H_{2(g)} + 2\,OH^-_{(aq)} + 2\,Na^+_{(aq)}$$