This exam should have 21 questions. The point values are given with each question. Bubble in your answer choices on the bubblehseet provided. Your score is based on what you bubble on the bubblesheet and not what is circled on the exam.

Standand Potentials at 25° C	E°
$F_2(g) + 2\ e^- \rightleftharpoons 2\ F^-(aq)$	+2.870 V
$Au^+(aq) + e^- \rightleftharpoons Au(s)$	+1.690 V
$Ce^{4+}(aq) + e^- \rightleftharpoons Ce^{3+}(aq)$	+1.610 V
$Cl_2(g) + 2\ e^- \rightleftharpoons 2\ Cl^-(aq)$	+1.360 V
$O_2(g) + 4\ H^+(aq) + 4\ e^- \rightleftharpoons 2\ H_2O(\ell)$	+1.229 V
$MnO_2(s) + 4\ H^+(aq) + 2\ e^- \rightleftharpoons Mn^{2+} + 2\ H_2O(\ell)$	+1.224 V
$Pd^{2+}(aq) + 2\ e^- \rightleftharpoons Pd(s)$	+0.915 V
$Ru^{2+}(aq) + 2\ e^- \rightleftharpoons Ru(s)$	+0.800 V
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.799 V
$PdO(s) + 2\ H^+ + 2\ e^- \rightleftharpoons Pd(s) + H_2O(\ell)$	+0.790 V
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.771 V
$Ru^{3+}(aq) + 3\ e^- \rightleftharpoons Ru(s)$	+0.600 V
$Cu^{2+}(aq) + 2\ e^- \rightleftharpoons Cu(s)$	+0.339 V
$Ru^{3+}(aq) + e^- \rightleftharpoons Ru^{2+}(aq)$	+0.240 V
$AgCl(s) + e^- \rightleftharpoons Ag(s) + Cl^-(aq)$	+0.222 V
$Sn^{4+}(aq) + 2\ e^- \rightleftharpoons Sn^{2+}(aq)$	+0.150 V
$2\ H^+(aq) + 2\ e^- \rightleftharpoons H_2(g)$	**0.000 V**
$Fe^{3+}(aq) + 3\ e^- \rightleftharpoons Fe(s)$	−0.040 V
$Sn^{2+}(aq) + 2\ e^- \rightleftharpoons Sn(s)$	−0.141 V
$Ni^{2+}(aq) + 2\ e^- \rightleftharpoons Ni(s)$	−0.236 V
$In^{3+}(aq) + 3\ e^- \rightleftharpoons In(s)$	−0.338 V
$Cd^{2+}(aq) + 2\ e^- \rightleftharpoons Cd(s)$	−0.400 V
$Fe^{2+}(aq) + 2\ e^- \rightleftharpoons Fe(s)$	−0.440 V
$FeCO_3(s) + 2\ e^- \rightleftharpoons Fe(s) + CO_3^{2-}$	−0.756 V
$Zn^{2+}(aq) + 2\ e^- \rightleftharpoons Zn(s)$	−0.762 V
$2\ H_2O(\ell) + 2\ e^- \rightleftharpoons H_2(g) + 2\ OH^-(aq)$	−0.830 V
$Mn^{2+}(aq) + 2\ e^- \rightleftharpoons Mn(s)$	−1.182 V
$Zn(OH)_2(s) + 2\ e^- \rightleftharpoons Zn(s) + 2\ OH^-(aq)$	−1.249 V
$Mn(OH)_2(s) + 2\ e^- \rightleftharpoons Mn(s) + 2\ OH^-(aq)$	−1.565 V
$Al^{3+}(aq) + 3\ e^- \rightleftharpoons Al(s)$	−1.660 V
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	−3.050 V

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1 Refer to the reduction potential table on the front page of the exam. (5 points)
Of the species listed below, which of the following is the strongest
oxidizing agent?

  A. Fe^{3+}

  B. Fe^{2+}

  C. H^+

  D. H_2

✔ E. Pd^{2+}

  F. Zn^{2+}

  G. Fe

  H. Zn

Explanation: The strongest oxidizing agent is the species most
likely to undergo reduction; in other words, it is the species with the
highest reduction potential.

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2 Which of the following metals is most easily oxidized? (5 points)

  A. Cu

  B. Ag

✔ C. Al

  D. Ni

Explanation: The metal that is most easily oxidized is the one with
the greatest oxidation potential. The table provided shows reduction
potentials for ions associated with these metals. The oxidation poten-
tial of the metal is the opposite of the standard reduction potential of
the associated ions.

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3 Consider the cell: (5 points)

$$Al(s) \mid Al^{3+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$$

What is serving as the anode in this voltaic cell?

✔ A. $Al(s)$

  B. $Al^{3+}(aq)$

  C. $Cu^{2+}(aq)$

  D. $Cu(s)$

Explanation: When using standard cell notation, the solid to the
furthest left side of the notation is solid substance serving as the an-
ode.

4   What is the standard cell potential for a voltaic cell constructed from   (5 points)
the Fe^{3+}/Fe^{2+} and Fe^{2+}/Fe set of redox couples?

   A. -1.21 V

   B. -0.33 V

   C. +0.01 V

   D. +0.33 V

✔ E. +1.21 V

Explanation: The standard cell potential is the difference in
the two 1/2 reaction potentials, +.771V and -.440V which equals
+1.211V. To force a cell to be voltaic, the Fe^{2+}/Fe redox couple must
be the anode (the potential you substract).

**5**   Identify the oxidation numbers for each respective element in lead(II)   (5 points)
nitrate, $Pb(NO_3)_2$.

   A. +2, +2, -2

✔ B. +2, +5, -2

   C. +2, +4, -6

   D. +2, +6, -2

   E. +4, +3, -1

   F. +4, +2, -6

Explanation: Oxygen has an oxidation number of -2. The poly-
atomic nitrate anion has an overall charge of -1, so nitrogen's oxida-
tion number be -5 in order to compensate for the three oxygen ions.
The lead is given as lead(II) ion, so its oxidation number in consid-
ered to be +2.

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6   For the following reaction of iron(III) bromide with chlorine, what is   (5 points)
the oxidizing agent?

$$3FeBr_3(aq) + 3Cl_2(g) \rightarrow 3FeCl_3(aq) + 3Br_2(\ell)$$
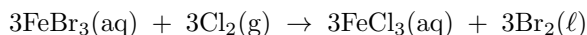
✔ A. $Cl_2(g)$

   B. $FeBr_3(aq)$

   C. $Fe(aq)$

   D. $Br_2(\ell)$

   E. $FeCl_3(aq)$

Explanation: Chlorine is being reduced from an oxidation state of 0
to a state of -1, so it is causing the bromide ion to be oxidized.

7   Balance the following redox reaction under acidic conditions.   (5 points)

$$NO_3^-(aq) + Sn^{2+}(aq) \rightarrow NO(g) + Sn^{4+}(aq)$$
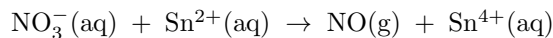
✔ A. $8H^+(aq) + 2NO_3^-(aq) + 3Sn^{2+}(aq) \rightarrow 3Sn^{4+}(aq) + 2NO(g) + 4H_2O(l)$

   B. $12H^+(aq) + 3NO_3^-(aq) + 2Sn^{2+}(aq) \rightarrow 2Sn^{4+}(aq) + 3NO(g) + 6H_2O(l)$

   C. $8H^+(aq) + 2NO_3^-(aq) + Sn^{2+}(aq) \rightarrow Sn^{4+}(aq) + 2NO(g) + 4H_2O(l)$

   D. $4H^+(aq) + NO_3^-(aq) + 2Sn^{2+}(aq) \rightarrow 2Sn^{4+}(aq) + NO(g) + 2H_2O(l)$

Explanation: You must separate the reaction into two half-reactions
and then balance the atoms, the charge, and the total electrons lost
and gained.

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8 $SO_3^{2-} \rightarrow SO_4^{2-}$ is a(n) _____ half reaction   (5 points)

in which _____ electrons are transferred.

   A. reduction, 1

   B. oxidation, 1

✔ C. oxidation, 2

   D. reduction, 2

   E. oxidation, 3

   F. reduction, 3

Explanation: Sulfur is being oxidized from +4 to +6, requiring the
loss of 2 electrons.

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9   A beaker contains an aqueous solution of Ni^{2+} ions and Zn^{2+} ions.   (5 points)
A small disc of nickel metal and a small disc of zinc metal are placed
into the beaker; they are not touching each other or anything else
except for the solution. Which of the following statements is true?

   A. Zinc ions are reduced on the zinc disc.

✔ B. Nickel ions are reduced on the zinc disc.

   C. Both nickel and zinc ions are reduced by water.

   D. Zinc ions are reduced on the nickel disc.

   E. Nickel ions are reduced on the nickel disc.

   F. Both nickel and zinc discs are oxidized by the water.

Explanation: Ni^{2+} is the stronger of the two possible oxidizing
agents and the $Zn(s)$ is the stronger of the two possible reducing
agents. Therefore the Ni^{2+} will react with the $Zn(s)$. This is the only
way that the net rxn has a positive potential.

10 A wacky jewelry maker wants to construct an electrochemical cell in   (5 points)
which he can plate out silver onto a gold (thus covering the expensive
yellow gold and making the ring look less valuable). He makes a cell
that reduces Ag^+ to Ag and oxidizes Au to Au^+. At standard condi-
tions, what type of cell is this, and will the reaction be spontaneous?

✔ A. Electrolytic, non-spontaneous

B. Electrolytic, spontaneous

C. Voltaic, non-spontanous

D. Voltaic, spontaneous

Explanation: As the jeweler wants to reduce the silver, the silver
will be the cathode and the gold oxidation will occur at the anode.
$E° = E°_{cat} - E°_{an}$ = +0.799 V - 1.69 V = -0.89 V. A negative standard
voltage is a non-spontaneous cell and therefore must be driven with
an external power source. This is an electrolytic cell.

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11 An aqueous solution of a hafnium (Hf, atomic number 72) com-   (5 points)
pound is in the laboratory. Unfortunately, the oxidation state of the
hafnium is not marked. Being a clever chemist you decide to figure it
out via electroplating. You hook up the cell and then run 12.4 amps
of current for 1.73 hours. After that you weigh the working electrode
and discover that you have deposited 35.7 grams of hafnium onto the
electrode. What is the oxidation state of the hafnium?

✔ A. +4

B. +3

C. +2

D. +1

E. $+1\frac{1}{2}$

F. $+\frac{1}{2}$

Explanation: 12.4 x 1.73 x 60 x 60/96485 = 0.800 C of charge.
35.7g/178.5 = 0.200 mol Hf. .8/.2 = 4 mol of electrons per mole of
Hf which means the charge/oxid number is +4.

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12 Which of the following substances is the active oxidizing agent during   (5 points)
the discharge of an alkaline battery or cell?

✔ A. manganese(IV) oxide

B. zinc

C. potassium hydroxide

D. carbon (graphite)

E. lithium ions

F. hypochlorite ions

Explanation: MnO_2 is the oxidizing agent and Zn is the reducing
agent.

13 A nickel wire is put into a strongly acidic aqueous solution of NaCl   (5 points)
and observed. Small bubbles form on the wire and rise to the top of
the solution. What is the identity of these bubbles?

✓ A. H_2 gas

  B. O_2 gas

  C. Cl_2 gas

  D. Na gas

  E. HCl gas

  F. ClO_2 gas

Explanation: The only thing the nickel can do is lose electrons (ox-
idize itself) to Ni_{2+} with a standard oxidizing potential of $+.23$ V
(table 1/2 reaction flipped). That is more than enough to reduce H^+
ions (at high conc) to H_2 gas (0.0 V $E°$). The other gases can only
be made via oxidation anyway which is impossible for just nickel (it
can't oxidize because it can't accept more electrons, metals are reduc-
ing agents, not oxidizing).

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14 A given chemical reaction has a standard potential of only $+25$ mV.   (5 points)
Approximately what ratio of products-to-reactants (prod/react)
would you expect the equilibrium mixture to be once the reaction
reaches equilibrium? You can assume a two electron transfer in the
reaction and simple 1:1 stoichiometry.

  A. 20/1

  B. 2/5

  C. 4/3

  D. 10/90

✓ E. 7/1

Explanation: $nFE° = RT \ln K$ which leads to $exp(\frac{nE°}{RT}) = K$
substituting in you get $exp(\frac{2 \cdot 0.025}{0.0257}) = 7 = K$

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15 The Hall process for the industrial production of aluminum involves   (5 points)
the electroplating of aluminum from a molten salt solution of alu-
mina (Al_2O_3). The metal is produced in the molten state and then
tapped off and hardened. A small portion of an aluminum production
plant is cranking away at 180000 amps each day (24 hours a day) on
a given set of cells while in production. How much aluminum is pro-
duced for this cell bank in one day?

✓ A. 1450 kg

  B. 8700 kg

  C. 483 kg

  D. 725 kg

  E. 24.2 kg

  F. 1120 kg

Explanation: 180000 x 24 x 60 x 60 / 96485 / 3 = 5.37e4 mol of Al.
x 26.98 = 1.45e6 g Al which is 1450 kg.

16 You construct a voltaic cell with standard concentrations of solutions   (5 points)
using $Cd(NO_3)_2$ and a Cd electrode as well as $Ni(NO_3)_2$ and a Ni
electrode. After the cell has been operating for some time you find
that the mass of the cathode has increased by 1.1 g. How much has
the mass of the anode changed?

✔A. it is 2.1 g less.

  B. it is 2.1 g more.

  C. it is 1.1 g less.

  D. it is 0.57 g more.

  E. it is 0.57 g less.

  F. the anode mass is unchanged

Explanation: For this cell to be a voltaic cell the reduction of Ni^{2+}
to Ni must be the cathode. For each mole of Ni formed, one mole of
Cd is oxidized and consumed. The mass ratio is $112.4/58.69 = 1.92$
g of Cd for every g of Ni. $1.1 \times 1.92 = 2.1$ g of Cd is consumed (less)
via oxidation.

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17 Calculate the K_{sp} of iron(II) carbonate, $FeCO_3$.   (5 points)

✔A. 2.1×10^{-11}

  B. 1.3×10^{-15}

  C. 2.8×10^{-26}

  D. 1.7×10^{-10}

  E. 4.8×10^{-17}

Explanation: You need two half-reactions that combine to give the
K_{sp} reaction: $FeCO_3 \rightleftharpoons Fe^{2+} + CO_3^{2-}$. Those are the 2 reactions at
-.440 V and -0.756 V on the standard potential table. The Fe/Fe^{2+}
reaction is reversed and this gives: $E° = -0.756 - -0.44 = -0.316$
V. Now use $nFE° = RT \ln K$. This can reduce to $\log K = (-0.316 \cdot
2)/0.05916 \rightarrow 10^{-10.68} = 2.07 \times 10^{-11}$.

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18 The cell shown is at 25°C. Calculate the   (5 points)
pH of the solution on the right side.

  A. 3.23

  B. 3.45

  C. 2.58

✔D. 4.15

  E. 3.79

  F. 1.00

  G. 7.00

  H. 5.32

+1.071 V

In(s)   Pt(s)

In^{3+}
(1 M)

Mn^{2+}
(1 M)

$MnO_2(s)$

H^+(?)
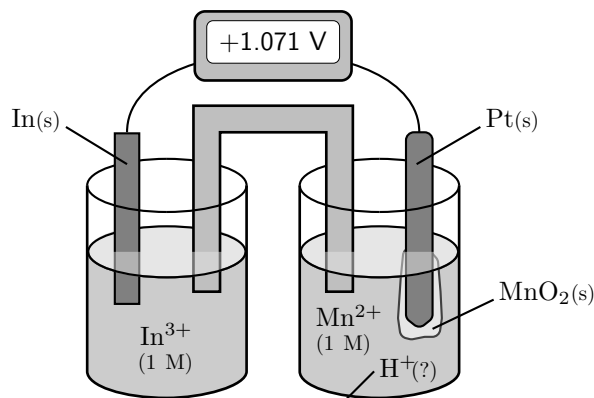
What is the pH of this solution?

Explanation: $E° = E_{cathode} - E°_{anode}$ The anode is a standard cell with $E° = -0.338$ V.
So the potential (non-std) for the cathode is $E_{cathode} = +1.071 + -0.338 = 0.733$ V. The $E°$
for MnO_2/Mn^{2+} is +1.224. The only non-std part of the electrode is the conc of H^+. Using the
Nernst equation we get $0.733 = 1.224 - 0.05916/2(\log Q)$ where $Q = 1/[H^+]^4$. Solving for Q we
get 3.97×10^{16}. Now we know that $[H^+]^{-4} = Q$. $[H^+] = 7.08 \times 10^{-5}$. pH is the -log of that number

19 Which of the battery types listed is a primary cell?   (5 points)

     A. Pb-acid

     B. Li-ion

✔ C. Zn-Carbon

     D. NiCd

     E. NiMH

Explanation: All listed are rechargeable (secondary cells) except for the Zn-C battery which is a primary cell and therefore not rechargeable.

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20 Two identical glasses of water are sitting side-by-side. They each have 250 mL of water in them at 25°C. You label one glass "J" and the other glass "K". You now add a tablespoon of $Ni(NO_3)_2$ to glass J and two tablespoons of $Ni(NO_3)_2$ to glass K. A salt bridge is used to connect the two glasses and a nickel wire is put into each glass. A voltmeter is then connected to the ends of the two nickel wires. What is the absolute value of the potential at this point?   (3 points)

     A. 115 mV

     B. 230 mV

     C. 59.2 mV

     D. 17.8 mV

✔ E. 8.9 mV

Explanation: This is a concentration cell because both half reactions are the same. One cell has twice as much concentration as the other which means $Q = 2$ or $Q = \frac{1}{2}$. So $\log Q = 0.301$ or -0.301V. $0.05916(.301)/2 = 0.0089$ V or 8.9 mV. Question asked for absolute value so sign doesn't matter here.

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21 Which direction are the electrons traveling in the connection between the two cells?   (2 points)

     A. electrons leave glass "K" and travel through the wire to glass "J"

✔ B. electrons leave glass "J" and travel thought the wire to glass "K"

Explanation: Increasing the concentration of Ni^2+ also increases the potential (more positive). The higher potential will be the cathode, meaning that cell (K) will pull electrons from the other cell (J) meaning electrons leave J and enter K.

Remember to bubble in ALL your answers BEFORE time is called. Sign your bubblesheet AND your exam. Then turn in BOTH your exam copy and your bubblesheet.