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Chemistry Lab

Exam

Booklet

STOUT
UNIVERSITY OF WISCONSIN
WISCONSIN'S POLYTECHNIC UNIVERSITY

April 23rd, 2022

State Tournament

PART – 2 of 2

Instructions: This exam consists of a set of experiments based on oxidation-reduction reactions and aqueous solutions worth 100 points and a multiple choice exam worth 100 points (200 points total).

Students may **NOT** write on the Experiment or Exam Booklet. Students may **only mark on their answer sheets. RedOX - Questions 1 to 50, Properties of Solutions - Questions 51 to 100.**

The "grade and team ranking" for this exam will be based on TOTAL POINTS out of 200 POSSIBLE POINTS. Be strategic, figure out the way that you and your team can bank as many points as possible in the time given. Place the answers to the lab experiments and multiple choice exam on the provided answer sheets. Answers not placed on the answer sheet will not be scored.

Ties will be broken by first the quality, accuracy, and completeness of the **experimental data and results**, followed by (if necessary) **selected multiple choice problems**.

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Potentially Useful Information:

$$C_1 \cdot V_1 = C_2 \cdot V_2$$

$$pH = -\log [H_3O^+]$$

TABLE 3.2 Common Acids and Bases

Strong Acids (Strong Electrolytes)		Soluble Strong Bases	
HCl (aq)	Hydrochloric acid	LiOH	Lithium hydroxide
HBr (aq)	Hydrobromic acid	NaOH	Sodium hydroxide
HI (aq)	Hydroiodic acid	KOH	Potassium hydroxide
HNO_3	Nitric acid	$Ba(OH)_2$	Barium hydroxide
$HClO_4$	Perchloric acid		
H_2SO_4	Sulfuric acid		
Weak Acids (Weak Electrolytes)*		**Weak Base (Weak Electrolyte)**	
H_3PO_4	Phosphoric acid	NH_3	Ammonia
H_2CO_3	Carbonic acid		
CH_3CO_2H	Acetic acid		
$H_2C_2O_4$	Oxalic acid		
$H_2C_4H_4O_6$	Tartaric acid		
$H_3C_6H_5O_7$	Citric acid		
$HC_9H_8O_4$	Aspirin		

* These are representative of hundreds of weak acids.

$$aA + bB \rightarrow cC + dD$$

$$E = E^\circ - \frac{R \cdot T}{n \cdot F} \cdot \ln\left(\frac{[C]^c \cdot [D]^d}{[A]^a \cdot [B]^b}\right)$$

E is the adjusted voltage of the cell
E° is the standard voltage of the cell
R is the ideal gas constant = 8.314 J/(K·mol)
T is the cell temperature in K
n is the number of moles of electrons transferred in the balance reaction
F is the Faraday constant = 9.649×10^4 J/(V·mol)

$$E = E^\circ - \frac{0.0592}{n} \cdot \log\left(\frac{[C]^c \cdot [D]^d}{[A]^a \cdot [B]^b}\right)$$

Solid metal electrodes are assumed to have a concentration of 1

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	K^+	Na^+	Li^+	Ba^{2+}	Ca^{2+}	Mg^{2+}	NH_4^+	Ag^+	Mn^{2+}	Fe^{2+}	Co^{2+}	Ni^{2+}	Cu^{2+}	Zn^{2+}	Pb^{2+}	Hg^{2+}	Al^{3+}	Cr^{3+}	Fe^{3+}	H^+
I^-	KI soluble	NaI soluble	LiI soluble	BaI_2 soluble	CaI_2 soluble	MgI_2 soluble	NH_4I soluble	AgI insoluble	MnI_2 soluble	FeI_2 soluble	CoI_2 soluble	NiI_2 soluble	CuI_2 not exist	ZnI_2 soluble	PbI_2 low	HgI_2 insoluble	AlI_3 soluble	CrI_3 soluble	FeI_3 soluble	HI soluble
Br^-	KBr soluble	NaBr soluble	LiBr soluble	$BaBr_2$ soluble	$CaBr_2$ soluble	$MgBr_2$ soluble	NH_4Br soluble	AgBr insoluble	$MnBr_2$ soluble	$FeBr_2$ soluble	$CoBr_2$ soluble	$NiBr_2$ soluble	$CuBr_2$ soluble	$ZnBr_2$ soluble	$PbBr_2$ low	$HgBr_2$ low	$AlBr_3$ soluble	$CrBr_3$ soluble	$FeBr_3$ soluble	HBr soluble
Cl^-	KCl soluble	NaCl soluble	LiCl soluble	$BaCl_2$ soluble	$CaCl_2$ soluble	$MgCl_2$ soluble	NH_4Cl soluble	AgCl insoluble	$MnCl_2$ soluble	$FeCl_2$ soluble	$CoCl_2$ soluble	$NiCl_2$ soluble	$CuCl_2$ soluble	$ZnCl_2$ soluble	$PbCl_2$ low	$HgCl_2$ soluble	$AlCl_3$ soluble	$CrCl_3$ soluble	$FeCl_3$ soluble	HCl soluble
SO_4^{2-}	K_2SO_4 soluble	Na_2SO_4 soluble	Li_2SO_4 soluble	$BaSO_4$ insoluble	$CaSO_4$ low	$MgSO_4$ soluble	$(NH_4)_2SO_4$ soluble	Ag_2SO_4 low	$MnSO_4$ soluble	$FeSO_4$ soluble	$CoSO_4$ soluble	$NiSO_4$ soluble	$CuSO_4$ soluble	$ZnSO_4$ soluble	$PbSO_4$ insoluble	$HgSO_4$ soluble	$Al_2(SO_4)_3$ soluble	$Cr_2(SO_4)_3$ soluble	$Fe_2(SO_4)_3$ soluble	H_2SO_4 soluble
NO_3^-	KNO_3 soluble	$NaNO_3$ soluble	$LiNO_3$ soluble	$Ba(NO_3)_2$ soluble	$Ca(NO_3)_2$ soluble	$Mg(NO_3)_2$ soluble	NH_4NO_3 soluble	$AgNO_3$ soluble	$Mn(NO_3)_2$ soluble	$Fe(NO_3)_2$ soluble	$Co(NO_3)_2$ soluble	$Ni(NO_3)_2$ soluble	$Cu(NO_3)_2$ soluble	$Zn(NO_3)_2$ soluble	$Pb(NO_3)_2$ soluble	$Hg(NO_3)_2$ soluble	$Al(NO_3)_3$ soluble	$Cr(NO_3)_3$ soluble	$Fe(NO_3)_3$ soluble	HNO_3 soluble
F^-	KF soluble	NaF soluble	LiF low	BaF_2 low	CaF_2 insoluble	MgF_2 low	NH_4F soluble	AgF soluble	MnF_2 low	FeF_2 low	CoF_2 soluble	NiF_2 soluble	CuF_2 soluble	ZnF_2 soluble	PbF_2 low	HgF_2 not exist	AlF_3 low	CrF_3 soluble	FeF_3 low	HF soluble
PO_4^{3-}	K_3PO_4 soluble	Na_3PO_4 soluble	Li_3PO_4 low	$Ba_3(PO_4)_2$ insoluble	$Ca_3(PO_4)_2$ insoluble	$Mg_3(PO_4)_2$ insoluble	$(NH_4)_3PO_4$ soluble	Ag_3PO_4 insoluble	$Mn_3(PO_4)_2$ insoluble	$Fe_3(PO_4)_2$ insoluble	$Co_3(PO_4)_2$ insoluble	$Ni_3(PO_4)_2$ insoluble	$Cu_3(PO_4)_2$ insoluble	$Zn_3(PO_4)_2$ insoluble	$Pb_3(PO_4)_2$ insoluble	$Hg_3(PO_4)_2$ insoluble	$AlPO_4$ insoluble	$CrPO_4$ insoluble	$FePO_4$ low	H_3PO_4 soluble
SO_3^{2-}	K_2SO_3 soluble	Na_2SO_3 soluble	Li_2SO_3 soluble	$BaSO_3$ insoluble	$CaSO_3$ insoluble	$MgSO_3$ low	$(NH_4)_2SO_3$ soluble	Ag_2SO_3 insoluble	$MnSO_3$ insoluble	$FeSO_3$ low	$CoSO_3$ insoluble	$NiSO_3$ insoluble	$CuSO_3$ not exist	$ZnSO_3$ low	$PbSO_3$ insoluble	$HgSO_3$ not exist	$Al_2(SO_3)_3$ not exist	$Cr_2(SO_3)_3$ not exist	$Fe_2(SO_3)_3$ not exist	H_2SO_3 soluble
CO_3^{2-}	K_2CO_3 soluble	Na_2CO_3 soluble	Li_2CO_3 soluble	$BaCO_3$ insoluble	$CaCO_3$ insoluble	$MgCO_3$ low	$(NH_4)_2CO_3$ soluble	Ag_2CO_3 insoluble	$MnCO_3$ insoluble	$FeCO_3$ insoluble	$CoCO_3$ insoluble	$NiCO_3$ insoluble	$CuCO_3$ insoluble	$ZnCO_3$ insoluble	$PbCO_3$ insoluble	$HgCO_3$ not exist	$Al_2(CO_3)_3$ not exist	$Cr_2(CO_3)_3$ not exist	$Fe_2(CO_3)_3$ not exist	H_2CO_3 low
S^{2-}	K_2S soluble	Na_2S soluble	Li_2S soluble	BaS soluble	CaS low	MgS not exist	$(NH_4)_2S$ soluble	Ag_2S insoluble	MnS insoluble	FeS insoluble	CoS insoluble	NiS insoluble	CuS insoluble	ZnS insoluble	PbS insoluble	HgS insoluble	Al_2S_3 not exist	Cr_2S_3 not exist	Fe_2S_3 not exist	H_2S low
SiO_3^{2-}	K_2SiO_3 soluble	Na_2SiO_3 soluble	Li_2SiO_3 low	$BaSiO_3$ low	$CaSiO_3$ insoluble	$MgSiO_3$ insoluble	$(NH_4)_2SiO_3$ not exist	Ag_2SiO_3 insoluble	$MnSiO_3$ insoluble	$FeSiO_3$ insoluble	$CoSiO_3$ insoluble	$NiSiO_3$ insoluble	$CuSiO_3$ insoluble	$ZnSiO_3$ insoluble	$PbSiO_3$ insoluble	$HgSiO_3$ not exist	$Al_2(SiO_3)_3$ not exist	$Cr_2(SiO_3)_3$ not exist	$Fe_2(SiO_3)_3$ not exist	H_2SiO_3 insoluble
OH^-	KOH soluble	NaOH soluble	LiOH soluble	$Ba(OH)_2$ soluble	$Ca(OH)_2$ low	$Mg(OH)_2$ insoluble	NH_4OH soluble	AgOH not exist	$Mn(OH)_2$ insoluble	$Fe(OH)_2$ insoluble	$Co(OH)_2$ insoluble	$Ni(OH)_2$ insoluble	$Cu(OH)_2$ insoluble	$Zn(OH)_2$ insoluble	$Pb(OH)_2$ insoluble	$Hg(OH)_2$ not exist	$Al(OH)_3$ insoluble	$Cr(OH)_3$ insoluble	$Fe(OH)_3$ insoluble	H_2O soluble

soluble - soluble (more than 1g per 100g of water)
low - low solubility (0.01g to 1g per 100g of water)
insoluble - insoluble (less than 0.01g per 100g of water)
not exist - do not exist in the aqueous environment

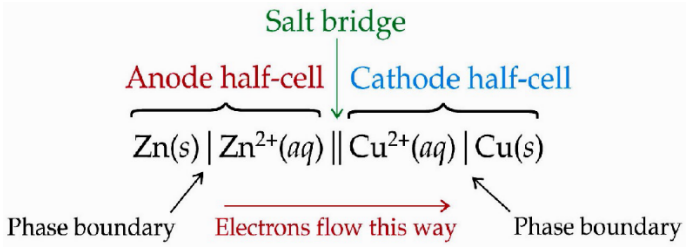
Soluble Compounds
Almost all salts of Na^+, K^+, NH_4^+
Salts of nitrate, NO_3^-
chlorate, ClO_3^-
perchlorate, ClO_4^-
acetate, $CH_3CO_2^-$

	Exceptions
Almost all salts of Cl^-, Br^-, I^-	Halides of Ag^+, Hg_2^{2+}, Pb^{2+}
Salts containing F^-	Fluorides of Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}
Salts of sulfate, SO_4^{2-}	Sulfates of Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}

Insoluble Compounds	Exceptions
Most salts of carbonate, CO_3^{2-}	Salts of NH_4^+ and the alkali metal cations
phosphate, PO_4^{3-}	
oxalate, $C_2O_4^{2-}$	Acid form when combined with H^+
chromate, CrO_4^{2-}	
sulfide, S^{2-}	
Most metal hydroxides, OH^- and metal oxides, O^{2-}	Alkali metal hydroxides and $Ba(OH)_2$

TABLE 2.4 Formulas and Names of Some Common Polyatomic Ions

Formula	Name	Formula	Name
CATION: Positive Ion			
NH_4^+	ammonium ion		
ANIONS: Negative Ions			
Based on a Group 4A element		**Based on a Group 7A element**	
CN^-	cyanide ion	ClO^-	hypochlorite ion
$CH_3CO_2^-$	acetate ion	ClO_2^-	chlorite ion
CO_3^{2-}	carbonate ion	ClO_3^-	chlorate ion
HCO_3^-	hydrogen carbonate ion (or bicarbonate ion)	ClO_4^-	perchlorate ion
Based on a Group 5A element		**Based on a transition metal**	
NO_2^-	nitrite ion	CrO_4^{2-}	chromate ion
NO_3^-	nitrate ion	$Cr_2O_7^{2-}$	dichromate ion
PO_4^{3-}	phosphate ion	MnO_4^-	permanganate ion
HPO_4^{2-}	hydrogen phosphate ion		
$H_2PO_4^-$	dihydrogen phosphate ion		
Based on a Group 6A element			
OH^-	hydroxide ion		
SO_3^{2-}	sulfite ion		
SO_4^{2-}	sulfate ion		
HSO_4^-	hydrogen sulfate ion (or bisulfate ion)		



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Key: Element Name / Atomic number / Symbol / Atomic weight (mean relative mass)

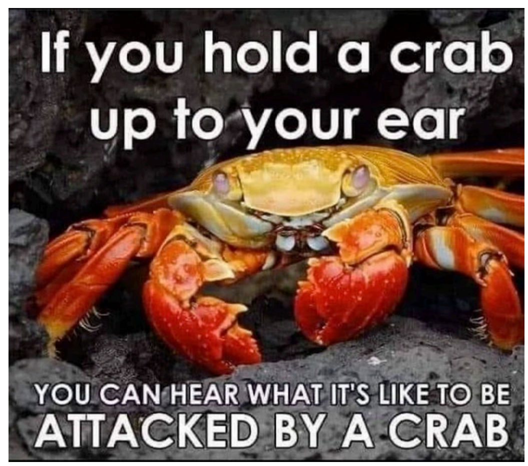
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Hydrogen 1 H 1.008																	Helium 2 He 4.0026
2	Lithium 3 Li 6.94	Beryllium 4 Be 9.0122											Boron 5 B 10.81	Carbon 6 C 12.011	Nitrogen 7 N 14.007	Oxygen 8 O 15.999	Fluorine 9 F 18.998	Neon 10 Ne 20.180
3	Sodium 11 Na 22.990	Magnesium 12 Mg 24.305											Aluminium 13 Al 26.982	Silicon 14 Si 28.085	Phosphorus 15 P 30.974	Sulfur 16 S 32.06	Chlorine 17 Cl 35.45	Argon 18 Ar 39.948
4	Potassium 19 K 39.098	Calcium 20 Ca 40.078(4)	Scandium 21 Sc 44.956	Titanium 22 Ti 47.867	Vanadium 23 V 50.942	Chromium 24 Cr 51.996	Manganese 25 Mn 54.938	Iron 26 Fe 55.845(2)	Cobalt 27 Co 58.933	Nickel 28 Ni 58.693	Copper 29 Cu 63.546(3)	Zinc 30 Zn 65.38(2)	Gallium 31 Ga 69.723	Germanium 32 Ge 72.63	Arsenic 33 As 74.922	Selenium 34 Se 78.96(3)	Bromine 35 Br 79.904	Krypton 36 Kr 83.798(2)
5	Rubidium 37 Rb 85.468	Strontium 38 Sr 87.62	Yttrium 39 Y 88.906	Zirconium 40 Zr 91.224(2)	Niobium 41 Nb 92.906(2)	Molybdenum 42 Mo 95.96(2)	Technetium 43 Tc [97.91]	Ruthenium 44 Ru 101.07(2)	Rhodium 45 Rh 102.91	Palladium 46 Pd 106.42	Silver 47 Ag 107.87	Cadmium 48 Cd 112.41	Indium 49 In 114.82	Tin 50 Sn 118.71	Antimony 51 Sb 121.76	Tellurium 52 Te 127.60(3)	Iodine 53 I 126.90	Xenon 54 Xe 131.29
6	Caesium 55 Cs 132.91	Barium 56 Ba 137.33	Lutetium 71 Lu 174.97	Hafnium 72 Hf 178.49(2)	Tantalum 73 Ta 180.95	Tungsten 74 W 183.84	Rhenium 75 Re 186.21	Osmium 76 Os 190.23(2)	Iridium 77 Ir 192.22	Platinum 78 Pt 195.08	Gold 79 Au 196.97	Mercury 80 Hg 200.59	Thallium 81 Tl 204.38	Lead 82 Pb 207.2	Bismuth 83 Bi 208.98	Polonium 84 Po [208.98]	Astatine 85 At [209.99]	Radon 86 Rn [222.02]
7	Francium 87 Fr [223.02]	Radium 88 Ra [226.03]	Lawrencium 103 Lr [262.11]	Rutherfordium 104 Rf [265.12]	Dubnium 105 Db [268.13]	Seaborgium 106 Sg [271.13]	Bohrium 107 Bh [270]	Hassium 108 Hs [277.15]	Meitnerium 109 Mt [276.15]	Darmstadtium 110 Ds [281.16]	Roentgenium 111 Rg [280.16]	Copernicium 112 Cn [285.17]	Ununtrium 113 Uut [284.18]	Flerovium 114 Fl [289.19]	Ununpentium 115 Uup [288.19]	Livermorium 116 Lv [293]	Ununseptium 117 Uus [294]	Ununoctium 118 Uuo [294]

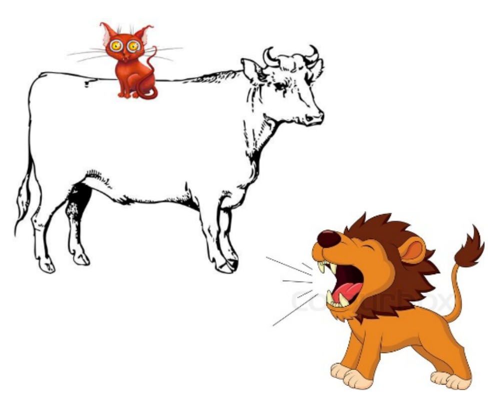
Period 6: 57-70 * ; Period 7: 89-102 **

Series														
*lanthanoids	Lanthanum 57 La 138.91	Cerium 58 Ce 140.12	Praseodymium 59 Pr 140.91	Neodymium 60 Nd 144.24	Promethium 61 Pm [144.91]	Samarium 62 Sm 150.36(2)	Europium 63 Eu 151.96	Gadolinium 64 Gd 157.25(3)	Terbium 65 Tb 158.93	Dysprosium 66 Dy 162.50	Holmium 67 Ho 164.93	Erbium 68 Er 167.26	Thulium 69 Tm 168.93	Ytterbium 70 Yb 173.05
**actinoids	Actinium 89 Ac [227.03]	Thorium 90 Th 232.04	Protactinium 91 Pa 231.04	Uranium 92 U 238.03	Neptunium 93 Np [237.05]	Plutonium 94 Pu [244.06]	Americium 95 Am [243.06]	Curium 96 Cm [247.07]	Berkelium 97 Bk [247.07]	Californium 98 Cf [251.08]	Einsteinium 99 Es [252.08]	Fermium 100 Fm [257.10]	Mendelevium 101 Md [258.10]	Nobelium 102 No [259.10]

Standard Electrode Potentials in Aqueous Solution at 25°C

Cathode (Reduction) Half-Reaction	Standard Potential E° (Volts)
$Li^+(aq) + e^- \leftrightarrow Li(s)$	-3.04
$K^+(aq) + e^- \leftrightarrow K(s)$	-2.92
$Ca^{2+}(aq) + 2e^- \leftrightarrow Ca(s)$	-2.76
$Na^+(aq) + e^- \leftrightarrow Na(s)$	-2.71
$Mg^{2+}(aq) + 2e^- \leftrightarrow Mg(s)$	-2.38
$Al^{3+}(aq) + 3e^- \leftrightarrow Al(s)$	-1.66
$Zn^{2+}(aq) + 2e^- \leftrightarrow Zn(s)$	-0.763
$Cr^{3+}(aq) + 3e^- \leftrightarrow Cr(s)$	-0.744
$Fe^{2+}(aq) + 2e^- \leftrightarrow Fe(s)$	-0.440
$Cd^{2+}(aq) + 2e^- \leftrightarrow Cd(s)$	-0.403
$Co^{2+}(aq) + 2e^- \leftrightarrow Co(s)$	-0.277
$Ni^{2+}(aq) + 2e^- \leftrightarrow Ni(s)$	-0.250
$Sn^{2+}(aq) + 2e^- \leftrightarrow Sn(s)$	-0.136
$Pb^{2+}(aq) + 2e^- \leftrightarrow Pb(s)$	-0.126
$2H^+(aq) + 2e^- \leftrightarrow H_2(g)$	0.000
$Sn^{4+}(aq) + 2e^- \leftrightarrow Sn^{2+}(aq)$	0.15
$Cu^{2+}(aq) + 2e^- \leftrightarrow Cu(s)$	0.337
$Ag^+(aq) + e^- \leftrightarrow Ag(s)$	0.799
$Co^{3+}(aq) + e^- \leftrightarrow Co^{2+}(aq)$	1.82
$S_2O_8^{2-}(aq) + 2e^- \leftrightarrow 2SO_4^{2-}(aq)$	2.01
$F_2(g) + 2e^- \leftrightarrow 2F^-(aq)$	2.87





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MULTIPLE CHOICE EXAM (100 Points)

Multiple Choice Answers must be placed on Answer Sheet provided.

Multiple Choice is scored as: TOTAL POINTS

OXIDATION REDUCTION (REDOX) REACTIONS

20.1 Oxidation-Reduction Reactions

1. Assuming the following reaction proceeds in the forward direction,
$2\ Ni^{2+}(aq) + Zn(s) \rightarrow 2\ Ni(s) + Zn^{2+}(aq)$
a) $Ni^{2+}(aq)$ is the reducing agent and Zn(s) is the oxidizing agent.
b) Zn(s) is the reducing agent and Ni(s) is the oxidizing agent.
c) $Ni^{2+}(aq)$ is the reducing agent and Ni(s) is the oxidizing agent.
d) Zn(s) is the reducing agent and $Zn^{2+}(s)$ is the oxidizing agent.
e) Zn(s) is the reducing agent and $Ni^{2+}(s)$ is the oxidizing agent.

2. The following reaction occurs spontaneously.
$2\ H^{+}(aq) + Sr(s) \rightarrow Sr^{2+}(aq) + H_2(g)$
Write the balanced reduction half-reaction.
a) $2\ H^{+}(aq) + 2\ e^{-} \rightarrow H_2(g)$
b) $2\ H^{+}(aq) \rightarrow H_2(g) + 2\ e^{-}$
c) $H_2(g) \rightarrow 2\ H^{+}(aq) + 2\ e^{-}$
d) $Sr(s) + 2\ e^{-} \rightarrow Sr^{2+}(aq)$
e) $Sr(s) \rightarrow Sr^{2+}(aq) + 2\ e^{-}$

3. Write a balanced half-reaction for the reduction of hydrogen peroxide to water in an acidic solution.
a) $2\ H_2O_2(l) \rightarrow 2\ H_2O(l) + O_2(g)$
b) $2\ H_2O_2(l) + 2e^{-} \rightarrow 2\ H_2O(l) + O_2(g)$
c) $H_2O_2(l) + 2\ H^{+}(aq) + 2\ e^{-} \rightarrow 2\ H_2O(l)$
d) $H_2O_2(l) + 4\ H^{+}(aq) + 2\ e^{-} \rightarrow 2\ H_2O(l) + H_2(g)$
e) $H_2O_2(l) + 2\ H^{+}(aq) + 4\ e^{-} \rightarrow 2\ H_2(g) + O_2(g)$

4. Write a balanced half-reaction for the reduction of $MnO_2(s)$ to $Mn(OH)_2(s)$ in a basic solution.
a) $MnO_2(s) + 2\ OH^{-}(aq) + 2\ e^{-} \rightarrow Mn(OH)_2(s) + O_2(g)$
b) $MnO_2(s) + 2\ H^{+}(aq) + 2\ e^{-} \rightarrow Mn(OH)_2(s)$
c) $MnO_2(s) + 2\ H^{+}(aq) \rightarrow Mn(OH)_2(s) + 2\ e^{-}$
d) $MnO_2(s) + 2\ H_2O(l) + 2\ e^{-} \rightarrow Mn(OH)_2(s) + 2\ OH^{-}(aq)$
e) $MnO_2(s) + 2\ OH^{-}(aq) \rightarrow Mn(OH)_2(s) + O_2(g)$

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5. Write a balanced chemical equation for the following reaction in an acidic solution.
$MnO_4^-(aq) + Fe(s) \rightarrow Mn^{2+}(aq) + Fe^{2+}(aq)$
a) $2\ MnO_4^-(aq) + 5\ Fe(s) + 16\ H^+(aq) \rightarrow 2\ Mn^{2+}(aq) + 5\ Fe^{2+}(aq) + 8\ H_2O(l)$
b) $MnO_4^-(aq) + Fe(s) + 16\ H^+(aq) \rightarrow Mn^{2+}(aq) + Fe^{2+}(aq) + 8\ H_2O(l)$
c) $MnO_4^-(aq) + Fe(s) \rightarrow Mn^{2+}(aq) + Fe^{2+}(aq) + 4\ H_2O(l)$
d) $2\ MnO_4^-(aq) + Fe(s) + 16\ H^+(aq) \rightarrow 2\ Mn^{2+}(aq) + Fe^{2+}(aq) + 8\ H_2O(l)$
e) $MnO_4^-(aq) + 5\ Fe(s) + 16\ H^+(aq) \rightarrow Mn^{2+}(aq) + 5\ Fe^{2+}(aq) + 8\ H_2O(l)$

6. Write a balanced chemical equation for the oxidation of $Fe^{2+}(aq)$ by concentrated nitric acid. Two products of the reaction are NO(g) and $Fe^{3+}(aq)$.
a) $HNO_3(aq) + Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + NO(g) + HO_2(l)$
b) $HNO_3(aq) + 3\ Fe^{2+}(aq) \rightarrow 3\ Fe^{3+}(aq) + NO(g) + HO_2(l)$
c) $2\ HNO_3(aq) + 2\ Fe^{2+}(aq) + 6\ H^+(aq) \rightarrow 3\ Fe^{3+}(aq) + 2\ NO(g) + 4\ H_2O(l)$
d) $4\ HNO_3(aq) + 3\ Fe^{2+}(aq) \rightarrow 3\ Fe^{3+}(aq) + NO(g) + 2H_2O(l) + 3\ NO_3^-(aq)$
e) $HNO_3(aq) + Fe^{2+}(aq) \rightarrow 3\ Fe^{3+}(aq) + NO(g)$

7. Write a balanced chemical equation for the following reaction in a basic solution.
$ClO^-(aq) + Cr(OH)_3(s) \rightarrow Cl^-(aq) + CrO_4^{2-}(aq)$
a) $3\ ClO^-(aq) + 2\ Cr(OH)_3(s) + 4\ OH^-(aq) \rightarrow 3\ Cl^-(aq) + 2\ CrO_4^{2-}(aq) + 5\ H_2O(l)$
b) $ClO^-(aq) + Cr(OH)_3(s) + 3\ OH^-(aq) \rightarrow Cl^-(aq) + CrO_4^{2-}(aq) + 3\ H_2O(l)$
c) $2\ ClO^-(aq) + 3\ Cr(OH)_3(s) + 3\ OH^-(aq) \rightarrow 2\ Cl^-(aq) + 3\ CrO_4^{2-}(aq) + 6\ H_2O(l)$
d) $4\ ClO^-(aq) + Cr(OH)_3(s) + 4\ OH^-(aq) \rightarrow Cl^-(aq) + CrO_4^{2-}(aq) + 6\ H_2O(l)$
e) $ClO^-(aq) + Cr(OH)_3(s) \rightarrow Cl^-(aq) + CrO_4^{2-}(aq) + 3\ H^+(aq)$

8. All of the following statements concerning voltaic cells are true EXCEPT
a) a salt bridge allows cations and anions to move between the half-cells.
b) electrons flow from the anode to the cathode in the external circuit.
c) oxidation occurs at the cathode.
d) a voltaic cell can be used as a source of energy.
e) a voltaic cell consists of two-half cells.

9. What is the correct cell notation for a voltaic cell based on the reaction below?
$Ag^+(aq) + Sn(s) \rightarrow Ag(s) + Sn^{2+}(aq)$
a) Ag(s) | $Ag^+(aq)$ || $Sn^{2+}(aq)$ | Sn(s)
b) Sn(s) || $Sn^{2+}(aq)$, $Ag^+(aq)$ | Ag(s)
c) Ag(s) || $Ag^+(aq)$, $Sn^{2+}(aq)$ || Sn(s)
d) Ag(s) | $Sn^{2+}(aq)$ || $Ag^+(aq)$ | Sn(s)
e) Sn(s) | $Sn^{2+}(aq)$ || $Ag^+(aq)$ | Ag(s)

10. Use the standard reduction potentials below to determine which element or ion is the best reducing agent.
$Pd^{2+}(aq) + 2\ e^- \rightarrow Pd(s)$ $E° = +0.90$ V
$2\ H^+(aq) + 2\ e^- \rightarrow H_2(g)$ $E° = 0.00$ V
$Mn^{2+}(aq) + 2\ e^- \rightarrow Mn(s)$ $E° = -1.18$ V
a) $Pd^{2+}(aq)$ b) Pd(s) c) $H^+(aq)$ d) $Mn^{2+}(aq)$ e) Mn(s)

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11. Consider the following half-reactions:

$Mg^{2+}(aq) + 2\ e^- \rightarrow Mg(s)$ $E° = -2.37$ V
$Al^{3+}(aq) + 3\ e^- \rightarrow Al(s)$ $E° = -1.66$ V
$Fe^{2+}(aq) + 2\ e^- \rightarrow Fe(s)$ $E° = -0.44$ V
$Sn^{2+}(aq) + 2\ e^- \rightarrow Sn(s)$ $E° = -0.14$ V
$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$ $E° = +0.34$ V

Which of the above metals or metal ions will oxidize Fe(s)?
a) $Cu^{2+}(aq)$ and $Sn^{2+}(aq)$
b) Cu(s) and Sn(s)
c) $Al^{3+}(aq)$ and $Mg^{2+}(aq)$
d) Al(s) and Mg(s)
e) Sn(s) and $Al^{3+}(aq)$

12. Given the following two half-reactions, write the overall reaction in the direction in which it is spontaneous and calculate the standard cell potential.

$Pb^{2+}(aq) + 2\ e^- \rightarrow Pb(s)$ $E° = -0.126$ V
$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$ $E° = +0.337$ V

a) $Pb^{2+}(aq) + Cu(s) \rightarrow Pb(s) + Cu^{2+}(aq)$ $E^o_{cell} = +0.463$ V
b) $Pb^{2+}(aq) + Cu(s) \rightarrow Pb(s) + Cu^{2+}(aq)$ $E^o_{cell} = +0.211$ V
c) $Pb(s) + Cu^{2+}(aq) \rightarrow Pb^{2+}(aq) + Cu(s)$ $E^o_{cell} = -0.211$ V
d) $Pb(s) + Cu^{2+}(aq) \rightarrow Pb^{2+}(aq) + Cu(s)$ $E^o_{cell} = +0.463$ V
e) $Pb(s) + Cu^{2+}(aq) \rightarrow Pb^{2+}(aq) + Cu(s)$ $E^o_{cell} = +0.926$ V

13. Which of the following equations is a correct form of the Nernst equation?

a) $E = E^\circ - \left(\frac{RT}{nF}\right)\ln Q$
b) $E = E^\circ + \log\left(\frac{RT}{nF}\right)$
c) $E = E^\circ - \left(\frac{nF}{RT}\right)\log Q$
d) $E^\circ = E - \left(\frac{RT}{nF}\right)\ln Q$
e) $E = E^\circ - \left(\frac{nF}{RT}\right)\ln Q$

14. A Faraday, *F*, is defined as
a) the charge on a single electron.
b) the charge, in coulombs, carried by one mole of electrons.
c) the voltage required to reduce one mole of reactant.
d) the moles of electrons required to reduce one mole of reactant.
e) the charge passed by one ampere of current in one second.

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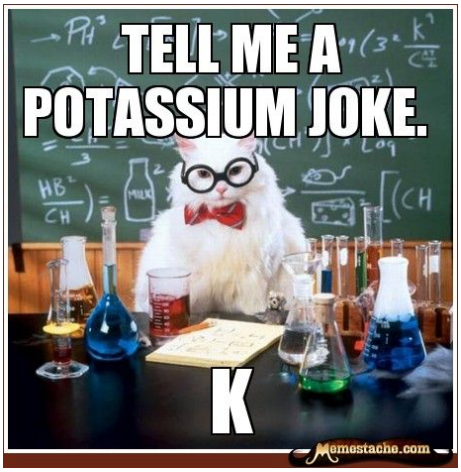

15. Calculate the cell potential, at 25 °C, based upon the overall reaction
$3\ Cr^{2+}(aq) + 2\ Al(s) \rightarrow 3\ Cr(s) + 2\ Al^{3+}(aq)$
if $[Cr^{2+}] = 0.15$ M and $[Al^{3+}] = 0.0040$ M. The standard reduction potentials are as follows:
$Al^{3+}(aq) + 3\ e^- \rightarrow Al(s)$ $E° = -1.66$ V
$Cr^{2+}(aq) + 2\ e^- \rightarrow Cr(s)$ $E° = -0.91$ V
a) -2.64 V b) -0.75 V c) +0.44 V d) +0.73 V e) +0.77 V

16. Which factor will increase the measured cell potential of the following galvanic cell?
$Pt \mid Sn^{4+}(aq, 1.0\ M), Sn^{2+}(aq, 1.0\ M) \parallel Cu^{2+}(aq, 0.200\ M) \mid Cu$
a) switching from a platinum to a graphite anode
b) increasing the size of the anode
c) decreasing the concentration of Cu^{2+}
d) increasing the concentration of Sn^{4+}
e) decreasing the temperature of the cell

17. What charge, in coulombs, is required to deposit 0.34 g Al(s) from a solution of $Al^{3+}(aq)$?
a) 4.1×10^2 C b) 3.6×10^3 C c) 7.2×10^3 C d) 3.3×10^4 C e) 9.8×10^4 C

18. What is the oxidation number of bromine in the BrO_3^- ion?
A) -1
B) +1
C) +3
D) +5
E) +7

19. Which element is oxidized in the reaction below?

$$Fe^{+2} + H^+ + Cr_2O_7^{-2} \rightarrow Fe^{+3} + Cr^{+3} + H_2O$$

A) Fe
B) Cr
C) O
D) H

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20. Which element is reduced in the reaction below?

$$Fe^{+2} + H^{+} + Cr_2O_7^{-2} \rightarrow Fe^{+3} + Cr^{+3} + H_2O$$

A) Fe
B) Cr
C) O
D) H

21. Which of the following reactions is a redox reaction?

(a) $K_2CrO_4 + BaCl_2 \rightarrow BaCrO_4 + 2KCl$
(b) $Pb_2^{2+} + 2Br^{-} \rightarrow PbBr$
(c) $Cu + S \rightarrow CuS$

A) (a) only
B) (b) only
C) (c) only
D) (a) and (c)
E) (b) and (c)

22. Which one of the following reactions is a redox reaction?
A) $NaOH + HCl \rightarrow NaCl + H_2O$
B) $Pb^{2+} + 2Cl^{-} \rightarrow PbCl_2$
C) $AgNO_3 + HCl \rightarrow HNO_3 + AgCl$
D) None of the above is a redox reaction.

23. Which substance is the reducing agent in the following reaction?
$Fe_2S_3 + 12HNO_3 \rightarrow 2Fe(NO_3)_3 + 3S + 6NO_2 + 6H_2O$

A) HNO_3
B) S
C) NO_2
D) Fe_2S_3
E) H_2O

24. Which substance is the oxidizing agent in the following reaction?
$Fe_2S_3 + 12HNO_3 \rightarrow 2Fe(NO_3)_3 + 3S + 6NO_2 + 6H_2O$

A) HNO_3
B) S
C) NO_2
D) Fe_2S_3
E) H_2O

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25. What is the coefficient of the permanganate ion when the following equation is balanced?

MnO_4^- + Br^- → Mn^{2+} + Br_2 (acidic solution)

A) 1
B) 2
C) 3
D) 5
E) 4

26. What is the coefficient of Fe^{3+} when the following equation is balanced?

CN^- + Fe^{3+} → CNO^- + Fe^{2+} (basic solution)

A) 1
B) 2
C) 3
D) 4
E) 5

27. The purpose of the salt bridge in an electrochemical cell is to _____.
A) maintain electrical neutrality in the half-cells via migration of ions.
B) provide a source of ions to react at the anode and cathode.
C) provide oxygen to facilitate oxidation at the anode.
D) provide a means for electrons to travel from the anode to the cathode.
E) provide a means for electrons to travel from the cathode to the anode.

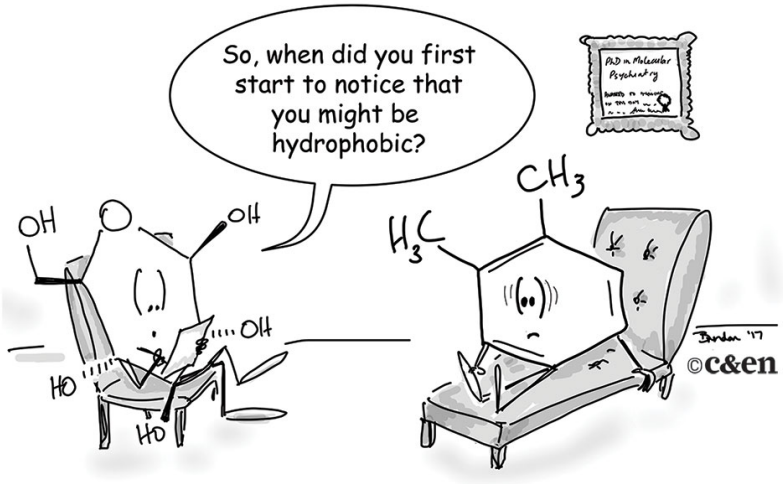

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Table 20.1

Half Reaction	E°(V)
$Li^+ + e^- \rightarrow Li\ (s)$	-3.05
$Ni^{2+} + 2e^- \rightarrow Ni\ (s)$	-0.28
$Pb^{2+} + 2e^- \rightarrow Pb\ (s)$	-0.126
$2H^+ + 2e^- \rightarrow H_2\ (g)$	0
$Cu^{2+} + 2e^- \rightarrow Cu\ (s)$	+0.34
$I_2\ (s) + 2e^- \rightarrow 2I^-\ (aq)$	+0.536
$Fe^{3+}\ (aq) + e^- \rightarrow Fe^{2+}\ (aq)$	+0.771
$Ag^+ + e^- \rightarrow Ag\ (s)$	+0.799
$O_2\ (g) + 4H^+\ (aq) + 4e^- \rightarrow 2H_2O\ (l)$	+1.23
$Br_2\ (l) + 2e^- \rightarrow 2Br^-\ (aq)$	+1.065
$Cl_2\ (g) + 2e^- \rightarrow 2Cl^-\ (aq)$	+1.359
$F_2\ (g) + 2e^- \rightarrow 2F^-\ (aq)$	+2.87

28. Which of the halogens in Table 20.1 is the strongest oxidizing agent?

A) Cl_2

B) Br_2

C) F_2

D) I_2

E) All of the halogens have equal strength as oxidizing agents.

Table 20.2

Half-reaction	E° (V)
$Cr^{3+}\ (aq) + 3e^- \rightarrow Cr\ (s)$	-0.74
$Fe^{2+}\ (aq) + 2e^- \rightarrow Fe\ (s)$	-0.440
$Sn^{4+}\ (aq) + 2e^- \rightarrow Sn^{2+}\ (aq)$	+0.154
$Fe^{3+}\ (aq) + e^- \rightarrow Fe^{2+}\ (s)$	+0.771

29. Which of the following reactions will occur spontaneously as written?

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

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

C) $Sn^{4+}\ (aq) + Fe^{2+}\ (aq) \rightarrow Sn^{2+}\ (aq) + Fe\ (s)$

D) $3Sn^{4+}\ (aq) + 2Cr\ (s) \rightarrow 2Cr^{3+}\ (aq) + 3Sn^{2+}\ (aq)$

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

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30. What is the anode in an alkaline battery?
A) MnO_2
B) KOH
C) Zn powder
D) Mn_2O_3
E) Pt

31. What is the cathode in an alkaline battery?
A) MnO_2
B) KOH
C) Zn powder
D) Mn_2O_3
E) Pt

32. The gain of electrons by an element is called _____.
A) reduction
B) oxidation
C) disproportionation
D) fractionation
E) sublimation

33. _____ is the oxidizing agent in the reaction below.

$$Cr_2O_7^{2-} + 6S_2O_3^{2-} + 14H^+ \rightarrow 2Cr^{3+} + 3S_4O_6^{2-} + 7H_2O$$

A) $Cr_2O_7^{2-}$
B) $S_2O_3^{2-}$
C) H^+
D) Cr^{3+}
E) $S_4O_6^{2-}$

34. _____ is the reducing agent in the reaction below.

$$Cr_2O_7^{2-} + 6S_2O_3^{2-} + 14H^+ \rightarrow 2Cr^{3+} + 3S_4O_6^{2-} + 7H_2O$$

A) $Cr_2O_7^{2-}$
B) $S_2O_3^{2-}$
C) H^+
D) Cr^{3+}
E) $S_4O_6^{2-}$

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35. What is the oxidation number of manganese in MnO_2?

A) +3
B) +2
C) +1
D) +4
E) +7

36. The electrode at which oxidation occurs is called the _____.

A) oxidizing agent
B) cathode
C) reducing agent
D) anode
E) voltaic cell

37. The half-reaction occurring at the anode in the balanced reaction shown below is _____.

$$3MnO_4^-\,(aq) + 24H^+\,(aq) + 5Fe\,(s) \rightarrow 3Mn^{2+}\,(aq) + 5Fe^{3+}\,(aq) + 12H_2O\,(l)$$

A) $MnO_4^-\,(aq) + 8H^+\,(aq) + 5e^- \rightarrow Mn^{2+}\,(aq) + 4H_2O\,(l)$
B) $2MnO_4^-\,(aq) + 12H^+\,(aq) + 6e^- \rightarrow 2Mn^{2+}\,(aq) + 3H_2O\,(l)$
C) $Fe\,(s) \rightarrow Fe^{3+}\,(aq) + 3e^-$
D) $Fe\,(s) \rightarrow Fe^{2+}\,(aq) + 2e^-$
E) $Fe^{2+}\,(aq) \rightarrow Fe^{3+}\,(aq) + e^-$

38. The half-reaction occurring at the cathode in the balanced reaction shown below is _____.

$$3MnO_4^-\,(aq) + 24H^+\,(aq) + 5Fe\,(s) \rightarrow 3Mn^{2+}\,(aq) + 5Fe^{3+}\,(aq) + 12H_2O\,(l)$$

A) $MnO_4^-\,(aq) + 8H^+\,(aq) + 5e^- \rightarrow Mn^{2+}\,(aq) + 4H_2O\,(l)$
B) $2MnO_4^-\,(aq) + 12H^+\,(aq) + 6e^- \rightarrow 2Mn^{2+}\,(aq) + 3H_2O\,(l)$
C) $Fe\,(s) \rightarrow Fe^{3+}\,(aq) + 3e^-$
D) $Fe\,(s) \rightarrow Fe^{2+}\,(aq) + 2e^-$
E) $Fe^{2+}\,(aq) \rightarrow Fe^{3+}\,(aq) + e^-$

39. In a voltaic cell, electrons flow from the _____ to the _____.

A) salt bride, anode
B) anode, salt bridge
C) cathode, anode
D) salt bridge, cathode
E) anode, cathode

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Table 20.2

Half-reaction	E° (V)
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	-0.74
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.440
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.154
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(s)$	+0.771

40. The standard cell potential ($E°_{cell}$) for the voltaic cell based on the reaction below is _____ V.

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

A) +0.46
B) +0.617
C) +1.39
D) -0.46
E) +1.21

41. The standard cell potential ($E°_{cell}$) for the voltaic cell based on the reaction below is _____ V.

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

A) -1.45
B) +2.99
C) +1.51
D) +3.05
E) +1.57

42. The standard cell potential ($E°_{cell}$) for the voltaic cell based on the reaction below is _____ V.

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

A) +0.30
B) +2.80
C) +3.10
D) +0.83
E) -0.16

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43. A voltaic cell is constructed with two silver-silver chloride electrodes, where the half-reaction is

$$AgCl\ (s) + e^- \rightarrow Ag\ (s) + Cl^-\ (aq) \quad E° = +0.222\ V$$

The concentrations of chloride ion in the two compartments are 0.0222 M and 2.22 M, respectively. The cell emf is _____ V.
A) 0.212
B) 0.118
C) 0.00222
D) 22.2
E) 0.232

44. The standard cell potential ($E°_{cell}$) for the reaction below is +0.63 V. The cell potential for this reaction is _____ V when $[Zn^{2+}] = 3.5$ M and $[Pb^{2+}] = 2.0 \times 10^{-4}$ M.

$$Pb^{2+}\ (aq) + Zn\ (s) \rightarrow Zn^{2+}\ (aq) + Pb\ (s)$$

A) 0.50
B) 0.84
C) 0.39
D) 0.76
E) 0.63

45. The standard cell potential ($E°_{cell}$) for the reaction below is +1.10 V. The cell potential for this reaction is _____ V when the concentration of $[Cu^{2+}] = 1.0 \times 10^{-5}$ M and $[Zn^{2+}] = 3.5$ M.

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

A) 1.42
B) 1.26
C) 0.94
D) 0.78
E) 1.10

46. The standard emf for the cell using the overall cell reaction below is +0.48 V:

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

The emf generated by the cell when $[Ni^{2+}] = 2.50$ M and $[Zn^{2+}] = 0.100$ M is _____ V.
A) 0.40
B) 0.50
C) 0.52
D) 0.56
E) 0.44

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47. In which species does sulfur have the highest oxidation number?
A) S_8 (elemental form of sulfur)
B) H_2S
C) SO_2
D) H_2SO_3
E) K_2SO_4

48. Sodium does not occur in nature as Na (s) because _____.
A) it is easily reduced to Na^-
B) it is easily oxidized to Na^+
C) it reacts with water with great difficulty
D) it is easily replaced by silver in its ores
E) it undergoes a disproportionation reaction to Na^- and Na^+

49. Oxidation is the _____ and reduction is the _____.
A) gain of oxygen, loss of electrons
B) loss of oxygen, gain of electrons
C) loss of electrons, gain of electrons
D) gain of oxygen, loss of mass
E) gain of electrons, loss of electrons

50. Oxidation and _____ mean essentially the same thing.
A) activity
B) reduction
C) metathesis
D) decomposition
E) corrosion

Cop: "You know how fast you were going?"
Albert Einstein: "Speed is relative officer"

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AQUEOUS SOLUTIONS

51. If 8.19 g KIO_3 is dissolved in enough water to make 500.0 mL of solution, what is the molarity of the potassium iodate solution? The molar mass of KIO_3 is 214 g/mol.
    a) 1.64×10^{-2} M
    b) 1.91×10^{-2} M
    c) 7.65×10^{-2} M
    d) 3.51 M
    e) 16.4 M

52. If 5.15 g $Fe(NO_3)_3$ is dissolved in enough water to make exactly 150.0 mL of solution, what is the molar concentration of nitrate ion?
    a) 0.00319 M b) 0.0343 M c) 0.142 M d) 0.313 M e) 0.426 M

53. If 25.00 mL of 4.50 M NaOH(aq) is diluted with water to a volume of 750.0 mL, what is the molarity of the diluted NaOH(aq)?
    a) 0.0333 M b) 0.150 M c) 0.155 M d) 6.67 M e) 1.35×10^3 M

54. What is the definition of molality?
a) moles of solute per kg of solvent
b) grams of solute per kg of solution
c) grams of solute per liter of solution
d) moles of solute per liter of solvent
e) moles of solute per liter of solution

55. If 18.4 g KCl is dissolved in 2.50×10^2 g H_2O, what is the weight percent of KCl in the solution?
a) 0.972% b) 6.86% c) 7.36% d) 7.94% e) 97.2%

56. If 355 g of ethanol (C_2H_5OH) is added to 645 g of water, what is the molality of the ethanol?
a) 0.550 *m* b) 7.71 *m* c) 11.9 *m* d) 21.7 *m* e) 55.0 *m*

57. What is the molality of 7.59% by weight aqueous hydrochloric acid? The molar mass of HCl is 36.46 g/mol.
a) 0.208 *m* b) 2.08 *m* c) 2.25 *m* d) 2.76 *m* e) 2.99 *m*

58. What is the weight percent of acetic acid in 2.73 *m* CH_3CO_2H(aq)?
a) 3.95×10^{-5}% b) 0.0455% c) 2.73% d) 14.1% e) 16.4%

59. The weight percent of concentrated $HClO_4$(aq) is 70.5% and its density is 1.67 g/mL. What is the molarity of concentrated $HClO_4$?
a) 4.20 M b) 7.18 M c) 11.7 M d) 14.2 M e) 39.7 M

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60. Concentrated sodium hydroxide is 19.4 M and has a density of 1.54 g/mL. What is the molality of concentrated NaOH?
a) 12.6 *m* b) 19.8 *m* c) 25.4 *m* d) 29.9 *m* e) 50.4 *m*

61. If the concentration of potassium carbonate in water is 210 ppm, what is the molarity of $K_2CO_3(aq)$? The molar mass of K_2CO_3 is 138.2 g/mol. Assume the density of the solution is 1.00 g/mL.
a) 1.5×10^{-3} M b) 3.4×10^{-3} M c) 2.9×10^{-2} M d) 3.4×10^{-2} M e) 0.66 M

62. A 25 meter by 10 meter pool of water has a depth of 2.5 meters. What mass of silver ion is present in the reservoir if the concentration of silver ion is 0.13 ppm? (1 m^3 = 1000 L; assume the density of the solution is 1.00 g/mL)
a) 2.1×10^{-4} g b) 7.5×10^{-1} g c) 4.8 g d) 8.8 g e) 81 g

63. What concentration of potassium chloride (in ppm) is present in 7.1×10^{-5} M KCl(aq)? For very dilute aqueous solutions, you can assume the solution's density is 1.0 g/mL. The molar mass of KCl is 74.55 g/mol.
a) 0.095 ppm b) 0.53 ppm c) 1.1 ppm d) 5.3 ppm e) 11 ppm

64. What mass of $Zn(NO_3)_2$ must be diluted to a mass of 1.00 kg with H_2O to prepare 97 ppm $Zn^{2+}(aq)$?
a) 7.8×10^{-6} g b) 7.8×10^{-3} g c) 3.3×10^{-2} g d) 1.3×10^{-1} g e) 2.8×10^{-1} g

65. Ideally, colligative properties depend only on the
a) concentration of solute particles in a solution.
b) molar masses of the solute particles in a solution.
c) density of a solution.
d) hydrated radii of the molecules or ions dissolved in a solution.
e) partial pressure of the gases above the surface of a solution.

66. Which of the following aqueous solutions should have the lowest freezing point?
a) pure H_2O b) 1 *m* $MgBr_2$ c) 1 *m* RbI d) 1 *m* NH_3 e) 1 *m* $C_6H_{12}O_6$

67. Which of the following aqueous solutions should have the highest boiling point?
a) 0.50 *m* NaBr b) 0.50 *m* K_2SO_4 c) 0.50 *m* $CaBr_2$ d) 1.0 *m* KCl e) 1.5 *m* $C_6H_{12}O_6$

68. The freezing point depression constant for water is –1.86 °C/*m*. At what temperature will a solution containing 8.27 g $CaCl_2$ and 45.0 g H_2O begin to freeze? Assume that no ion-pairing occurs between Ca^{2+} and Cl^-.
a) -9.24 °C b) -4.62 °C c) -0.804 °C d) -0.749 °C e) +4.62 °C

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69. What is the molar mass of a nonpolar molecular compound if 3.42 grams dissolved in 41.8 grams benzene begins to freeze at 1.17 °C? The freezing point of pure benzene is 5.50 °C and the freezing point depression constant, K_{fp}, is -5.12 °C/*m*.

a) 2.89 g/mol b) 69.2 g/mol c) 96.7 g/mol d) 126 g/mol e) 358 g/mol

70. What is the boiling point of a solution containing 0.80 g caffeine, $C_8H_{10}N_4O_2$, dissolved in 13.20 g benzene? The boiling point of pure benzene is 80.1 °C and the boiling point elevation constant, K_{bp}, is 2.53 °C/*m*.

a) 79.8 °C b) 80.4 °C c) 80.9 °C d) 85.2 °C e) 88.2 °C

71. What mass of Na_2SO_4 must be dissolved in 75.0 grams of water to lower the freezing point by 2.50 °C? The freezing point depression constant, K_{fp}, of water is -1.86 °C/*m*. Assume the van't Hoff factor for Na_2SO_4 is 2.40.

a) 0.310 g b) 3.30 g c) 5.97 g d) 23.3 g e) 44.0 g

72. A 0.200 M K_2SO_4 solution is produced by _____.

A) dilution of 250.0 mL of 1.00 M K_2SO_4 to 1.00 L

B) dissolving 43.6 g of K_2SO_4 in water and diluting to a total volume of 250.0 mL

C) diluting 20.0 mL of 5.00 M K_2SO_4 solution to 500.0 mL

D) dissolving 20.2 g of K_2SO_4 in water and diluting to 250.0 mL, then diluting 25.0 mL of this solution to a total volume of 500.0 mL

E) dilution of 1.00 mL of 250 M K_2SO_3 to 1.00 L

73. Which solution has the same number of moles of KCl as 75.00 mL of 0.250*M* solution of KCl?

A) 20.0 mL of 0.200*M* solution of KCl
B) 25.0 mL of 0.175*M* solution of KCl
C) 129 mL of 0.145*M* solution of KCl
D) 50.0 mL of 0.125*M* solution of KCl
E) 100 mL of 0.0500*M* solution of KCl

74. A strong electrolyte is one that _____ completely in solution.

A) reacts
B) associates
C) disappears
D) ionizes

75. A weak electrolyte exists predominantly as _____ in solution.

A) atoms
B) ions
C) molecules
D) electrons
E) an isotope

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76. What is the concentration (M) of a NaCl solution prepared by dissolving 9.3 g of NaCl in sufficient water to give 350 mL of solution?

A) 18
B) 0.16
C) 0.45
D) 27
E) 2.7×10^{-2}

77. What are the respective concentrations (M) of K^+ and PO_4^{3-} afforded by dissolving 0.800 mol K_3PO_4 in water and diluting to 1.63 L?

A) 0.800 and 0.800
B) 0.491 and 0.491
C) 0.800 and 0.491
D) 1.44 and 0.491
E) 0.489 and 0.163

78. The molarity (M) of an aqueous solution containing 52.5 g of sucrose ($C_{12}H_{22}O_{11}$) in 35.5 mL of solution is _____.

A) 5.46
B) 1.48
C) 0.104
D) 4.32
E) 1.85

79. How many grams of sodium chloride are there in 55.0 mL of a 1.90 M aqueous solution of sodium chloride?

A) 0.105
B) 6.11
C) 3.21
D) 6.11×10^3
E) 12.2

80. How many grams of NaOH (MW = 40.0) are there in 500.0 mL of a 0.225 M NaOH solution?

A) 0.00219
B) 114
C) 14.0
D) 4.50
E) 0.113

81. There are _____ mol of bromide ions in 0.500 L of a 0.100 M solution of $AlBr_3$.

A) 0.0500
B) 0.450
C) 0.150
D) 0.167
E) 0.500

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82. A solution is prepared by adding 1.60 g of solid NaCl to 50.0 mL of 0.100 M $CaCl_2$. What is the molarity of chloride ion in the final solution? Assume that the volume of the final solution is 50.0 mL.
A) 0.747
B) 0.647
C) 0.132
D) 0.232
E) 0.547

83. The phrase "like dissolves like" refers to the fact that _____.
A) gases can only dissolve other gases
B) polar solvents dissolve polar solutes and nonpolar solvents dissolve nonpolar solutes
C) solvents can only dissolve solutes of similar molar mass
D) condensed phases can only dissolve other condensed phases
E) polar solvents dissolve nonpolar solutes and vice versa

84. A saturated solution _____.
A) contains as much solvent as it can hold
B) contains no double bonds
C) contains dissolved solute in equilibrium with undissolved solute
D) will rapidly precipitate if a seed crystal is added
E) cannot be attained

85. An unsaturated solution is one that _____.
A) has no double bonds
B) contains the maximum concentration of solute possible, and is in equilibrium with undissolved solute
C) has a concentration lower than the solubility
D) contains more dissolved solute than the solubility allows
E) contains no solute

86. A solution with a concentration higher than the solubility is _____.
A) is not possible
B) is unsaturated
C) is supercritical
D) is saturated
E) is supersaturated

87. Which one of the following is least soluble in water?
A) CH_3OH
B) $CH_3CH_2CH_2OH$
C) CH_3CH_2OH
D) $CH_3CH_2CH_2CH_2OH$
E) $CH_3CH_2CH_2CH_2CH_2OH$

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88. A solution contains 28% phosphoric acid by mass. This means that _____.
A) 1 mL of this solution contains 28 g of phosphoric acid
B) 1 L of this solution has a mass of 28 g
C) 100 g of this solution contains 28 g of phosphoric acid
D) 1 L of this solution contains 28 mL of phosphoric acid
E) the density of this solution is 2.8 g/mL

89. Calculate the molality of a 25.4% (by mass) aqueous solution of phosphoric acid (H_3PO_4).
A) 2.59 m
B) 3.47 m
C) 4.45 m
D) 25.4 m
E) The density of the solution is needed to solve the problem.

90. Calculate the molarity of a 25.4% (by mass) aqueous solution of phosphoric acid (H_3PO_4).
A) 2.59 m
B) 3.47 m
C) 4.45 m
D) 25.4 m
E) The density of the solution is needed to solve the problem.

91. A 1.35 m aqueous solution of compound X had a boiling point of 101.4°C. Which one of the following could be compound X? The boiling point elevation constant for water is 0.52°C/m.
A) CH_3CH_2OH
B) $C_6H_{12}O_6$
C) Na_3PO_4
D) KCl
E) $CaCl_2$

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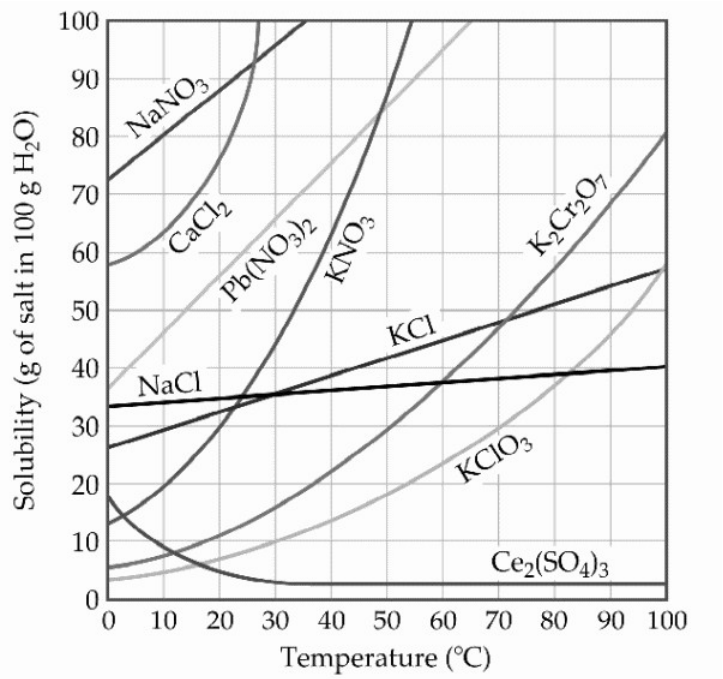

92. A sample of potassium nitrate (49.0 g) is dissolved in 101 g of water at 100°C, with precautions taken to avoid evaporation of any water. The solution is cooled to 30.0°C and no precipitate is observed. This solution is _____.

A) hydrated
B) placated
C) saturated
D) unsaturated
E) supersaturated

93. A sample of potassium chlorate (15.0 g) is dissolved in 201 g of water at 70°C, with precautions taken to avoid evaporation of any water. The solution is cooled to 30.0°C and no precipitate is observed. This solution is _____.

A) hydrated
B) miscible
C) saturated
D) unsaturated
E) supersaturated

94. A sample of potassium nitrate (49.0 g) is dissolved in 101 g of water at 100°C, with precautions taken to avoid evaporation of any water. The solution is cooled to 30.0°C and a small amount of precipitate is observed. This solution is _____.

A) hydrated
B) placated
C) saturated
D) unsaturated
E) supersaturated

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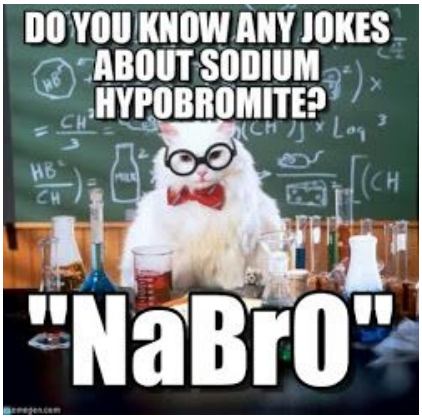

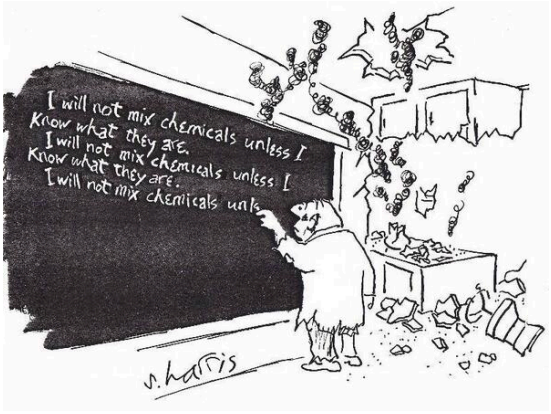

95. The solubility of $MnSO_4$ monohydrate in water at 20°C is 70.0 g per 100.0 mL of water. A solution at 20°C that is 4.22 *M* in $MnSO_4$ monohydrate is best described as a(n) _____ solution. The formula weight of $MnSO_4$ monohydrate is 168.97 g/mol.

A) hydrated
B) solvated
C) saturated
D) unsaturated
E) supersaturated

96. A solution is prepared by dissolving 23.7 g of $CaCl_2$ in 375 g of water. The density of the resulting solution is 1.05 g/mL. The concentration of Cl^- in this solution is _____ M.

A) 0.214
B) 0.562
C) 1.12
D) 1.20
E) 6.64×10^{-2}

97. What is the molality of sodium chloride in solution that is 13.0% by mass sodium chloride and that has a density of 1.10 g/mL?

A) 2.23
B) 1.30
C) 2.56
D) 2.03
E) 1.10

98. What is the freezing point (°C) of a solution prepared by dissolving 11.3 g of $Ca(NO_3)_2$ (formula weight = 164 g/mol) in 115 g of water? The molal freezing point depression constant for water is 1.86°C/m.

A) -3.34
B) -1.11
C) 3.34
D) 1.11
E) 0.00

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99. A solution containing 20.0 g of an unknown liquid and 110.0 g water has a freezing point of -1.32 °C. Given K_f = 1.86°C/m for water, the molar mass of the unknown liquid is _____g/mol.

A) 256
B) 69.0
C) 333
D) 619
E) 78.1

100. George is making spaghetti for dinner. He places 4.01 kg of water in a pan and brings it to a boil. Before adding the pasta, he adds 58 g of table salt (NaCl) to the water and again brings it to a boil. The temperature of the salty, boiling water is _____°C.

Assume a pressure of 1.00 atm and negligible evaporation of water. K_b for water is 0.52°C/m.

A) 99.87
B) 100.26
C) 100.13
D) 99.74
E) 100.00