Fundamentals of Engineering (FE) General Exam
Review Program
March 3rd ~ April 12th, 2010

Chemistry

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Overview

- Introduction – limited time, few items covered
- FE Supplied-Reference Handbook – what's exciting in the Chemistry section, p 100-103
- Example FE General Exam Questions – cover as many as we can
- Summary

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CHEMISTRY

Avogadro's Number: The number of elementary particles in a mol of a substance.

1 mol = 1 gram mole

1 mol = 6.02×10^{23} particles

A *mol* is defined as an amount of a substance that contains as many particles as 12 grams of ^{12}C (carbon 12). The elementary particles may be atoms, molecules, ions, or electrons.

ACIDS, BASES, and pH (aqueous solutions)

$$pH = \log_{10}\left(\frac{1}{[H^+]}\right), \text{ where}$$

$[H^+]$ = molar concentration of hydrogen ion, in gram moles per liter

Acids have pH < 7.

Bases have pH > 7.

ELECTROCHEMISTRY

Cathode – The electrode at which reduction occurs.

Anode – The electrode at which oxidation occurs.

Oxidation – The loss of electrons.

Reduction – The gaining of electrons.

Oxidizing Agent – A species that causes others to become

Equilibrium Constant of a Chemical Reaction

$$aA + bB \rightleftarrows cC + dD$$

$$K_{eq} = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

Le Chatelier's Principle for Chemical Equilibrium – When a stress (such as a change in concentration, pressure, or temperature) is applied to a system in equilibrium, the equilibrium shifts in such a way that tends to relieve the stress.

Heats of Reaction, Solution, Formation, and Combustion – Chemical processes generally involve the absorption or evolution of heat. In an endothermic process, heat is absorbed (enthalpy change is positive). In an exothermic process, heat is evolved (enthalpy change is negative).

Solubility Product of a slightly soluble substance *AB:*

$$A_mB_n \rightarrow mA^{n+} + nB^{m-}$$

Solubility Product Constant = $K_{SP} = [A^+]^m [B^-]^n$

Metallic Elements – In general, metallic elements are distinguished from nonmetallic elements by their luster, malleability, conductivity, and usual ability to form positive ions.

Nonmetallic Elements – In general, nonmetallic elements are not malleable, have low electrical conductivity, and rarely

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Oxidizing Agent – A species that causes others to become oxidized.

Reducing Agent – A species that causes others to be reduced.

Cation – Positive ion

Anion – Negative ion

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DEFINITIONS

Molarity of Solutions – The number of gram moles of a substance dissolved in a liter of solution.

Molality of Solutions – The number of gram moles of a substance per 1,000 grams of solvent.

Normality of Solutions – The product of the molarity of a solution and the number of valence changes taking place in a reaction.

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DEFINITIONS cont.

Equivalent Mass – The number of parts by mass of an element or compound which will combine with or replace directly or indirectly 1.008 parts by mass of hydrogen, 8.000 parts of oxygen, or the equivalent mass of any other element or compound. For all elements, the atomic mass is the product of the equivalent mass and the valence.

Molar Volume of an Ideal Gas [at 0°C (32°F) and 1 atm (14.7 psia)]; 22.4 L/(g mole) [359 ft^3/(lb mole)].

Mole Fraction of a Substance – The ratio of the number of moles of a substance to the total moles present in a mixture of substances. Mixture may be a solid, a liquid solution, or a gas.

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DEFINITIONS cont.

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DEFINITIONS cont. …

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DEFINITIONS cont. …

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DEFINITIONS cont. …

Faraday's Law – In the process of electrolytic changes, equal quantities of electricity charge or discharge equivalent quantities of ions at each electrode. One gram equivalent weight of matter is chemically altered at each electrode for 96,485 coulombs, or one Faraday, of electricity passed through the electrolyte.

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DEFINITIONS cont.

A *catalyst* is a substance that alters the rate of a chemical reaction and may be recovered unaltered in nature and amount at the end of the reaction. The catalyst does not affect the position of equilibrium of a reversible reaction.

The *atomic number* is the number of protons in the atomic nucleus. The atomic number is the essential feature which distinguishes one element from another and determines the position of the element in the periodic table.

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DEFINITIONS cont. …

Boiling Point Elevation – The presence of a nonvolatile solute in a solvent raises the boiling point of the resulting solution compared to the pure solvent; i.e., to achieve a given vapor pressure, the temperature of the solution must be higher than that of the pure substance.

Freezing Point Depression – The presence of a solute lowers the freezing point of the resulting solution compared to that of the pure solvent.

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PERIODIC TABLE OF ELEMENTS

1 **H** 1.0079																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.179
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.981	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.941	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.921	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57* **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.02	89** **Ac** 227.03	104 **Rf** (261)	105 **Ha** (262)													
*Lanthanide Series			58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97	
**Actinide Series			90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** 237.05	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)	

Atomic Number
Symbol
Atomic Weight

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* Measured at 25 °C
Reactions are written as anode half-cells.
Arrows are reversed for cathode half-cells.

NOTE: In some Chemistry texts, the reactions and signs are reversed

Standard Oxidation Potentials for Corrosion Reactions*	
Corrosion Reaction	**Potential, E_o, Volts vs. Normal Hydrogen Electrode**
$Au \rightarrow Au^{3+} + 3e^-$	–1.498
$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$	–1.229
$Pt \rightarrow Pt^{2+} + 2e^-$	–1.200
$Pd \rightarrow Pd^{2+} + 2e^-$	–0.987
$Ag \rightarrow Ag^+ + e^-$	–0.799
$2Hg \rightarrow Hg_2^{2+} + 2e^-$	–0.788
$Fe^{2+} \rightarrow Fe^{3+} + e^-$	–0.771
$4(OH)^- \rightarrow O_2 + 2H_2O + 4e^-$	–0.401
$Cu \rightarrow Cu^{2+} + 2e^-$	–0.337
$Sn^{2+} \rightarrow Sn^{4+} + 2e^-$	–0.150
$H_2 \rightarrow 2H^+ + 2e^-$	0.000
$Pb \rightarrow Pb^{2+} + 2e^-$	+0.126
$Sn \rightarrow Sn^{2+} + 2e^-$	+0.136
$Ni \rightarrow Ni^{2+} + 2e^-$	+0.250
$Co \rightarrow Co^{2+} + 2e^-$	+0.277
$Cd \rightarrow Cd^{2+} + 2e^-$	+0.403
$Fe \rightarrow Fe^{2+} + 2e^-$	+0.440
$Cr \rightarrow Cr^{3+} + 3e^-$	+0.744
$Zn \rightarrow Zn^{2+} + 2e^-$	+0.763
$Al \rightarrow Al^{3+} + 3e^-$	+1.662
$Mg \rightarrow Mg^{2+} + 2e^-$	+2.363
$Na \rightarrow Na^+ + e^-$	+2.714
$K \rightarrow K^+ + e^-$	+2.925
* Measured at 25°C. Reactions are written as anode half-cells.	

Date: 04/12/10

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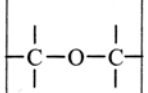
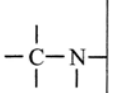
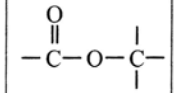
IMPORTANT FAMILIES OF ORGANIC COMPOUNDS

	FAMILY											
	Alkane	**Alkene**	**Alkyne**	**Arene**	**Haloalkane**	**Alcohol**	**Ether**	**Amine**	**Aldehyde**	**Ketone**	**Carboxylic Acid**	**Ester**
Specific Example	CH_3CH_3	$H_2C=CH_2$	$HC\equiv CH$		CH_3CH_2Cl	CH_3CH_2OH	CH_3OCH_3	CH_3NH_2	$CH_3\overset{O}{\overset{\|}{C}}H$	$CH_3\overset{O}{\overset{\|}{C}}CH_3$	$CH_3\overset{O}{\overset{\|}{C}}OH$	$CH_3\overset{O}{\overset{\|}{C}}OCH_3$
IUPAC Name	Ethane	Ethene or Ethylene	Ethyne or Acetylene	Benzene	Chloroethane	Ethanol	Methoxy-methane	Methan-amine	Ethanal	Acetone	Ethanoic Acid	Methyl ethanoate
Common Name	Ethane	Ethylene	Acetylene	Benzene	Ethyl chloride	Ethyl alcohol	Dimethyl ether	Methyl-amine	Acetal-dehyde	Dimethyl ketone	Acetic Acid	Methyl acetate
General Formula	RH	$RCH=CH_2$ $RCH=CHR$ $R_2C=CHR$ $R_2C=CR_2$	$RC\equiv CH$ $RC\equiv CR$	ArH	RX	ROH	ROR	RNH_2 R_2NH R_3N	$R\overset{O}{\overset{\|}{C}}H$	$R_1\overset{O}{\overset{\|}{C}}R_2$	$R\overset{O}{\overset{\|}{C}}OH$	$R\overset{O}{\overset{\|}{C}}OR$
Functional Group	C–H and C–C bonds		$-C\equiv C-$	Aromatic Ring								

End of Chemistry Section
In Handbook