Part A: Do Questions 1 through 12

1. The figure below illustrates the concentration of dissolved oxygen, nitrate and iron in the North Pacific as a function of depth below the surface.
a) Report the concentration of all three species as ppm, ppb or pptr (as appropriate) at 1 km depth. [3]
b) Provide an explanation for the concentration trends from surface to 1 km. [3]

a)

O_2: _____

NO_3^-: _____

Fe: _____

b)

2. Methylmercury has a residence time in the body of 55 days. If an individual ingesting an average of 4 L per day of water contaminated with 10. ppb (as Hg), what is body load once a steady state is obtained (assume 100% uptake). [3]

_____ mg Hg

3. Provide an *example* (structural formula, where applicable) and a removal/treatment strategy for ANY THREE of the following. [6]

a) hardness ions

b) polyaromatic hydrocarbon

c) colloidal suspended solid

d) heavy metal ions

4. A water sample has a pH of 8.6 and a measured total alkalinity of 140 mg/L $CaCO_3$.
a) Determine the molar concentration of the three contributing species. [3]
b) Estimate the molar concentration of calcium ion, assuming it to be the only major cation present. [1]

[ ] = _____

[ ] = _____

[ ] = _____

$[Ca^{2+}]$ = _____

5. Match each of the following water contaminants with a viable treatment/removal agent. In each case, describe the chemical fate of the contaminant. (*note: more than one contaminant may be treated by the same additive*) [5]

a) nitrates	i) alum
b) THM's	ii) Cl_2
c) Pb^{2+}	iii) activated carbon
d) suspended solids	iv) lime/H_2S
e) phosphates	v) none of the above

6. Comment briefly on FOUR of the following, using chemical equilibria to illustrate your answer. [8]

a) Affect of pNTA on the mobility of cadmium contaminated lake sediments.

b) Affect of pH on the effectiveness of hypochlorous acid disinfection.

c) The effect of pH on the mobility of metal ions in soils remediated with biosolids.

d) The effect of pe on the toxicity of arsenic species.

e) The effect of increased temperature on the solubility of $CaCO_3$.

7. At 25^oC, the K_{sp} of $Zn(OH)_2$ is 1.2×10^{-17}. At what pH is a solution containing 15 mg/L of zinc as $Zn^{2+}(aq)$ saturated with respect to zinc (II) hydroxide? [4]

pH = _____

8. A water sample from an acid mine site on Eastern Vancouver Island has a measured pH = 4.2 and analyzed to contain $[Fe^{3+}] = 8.0 \times 10^{-3}$ M and $[Fe^{2+}] = 4.0 \times 10^{-4}$ M.

a) Assuming the system is at equilibrium, estimate the pe for this water. [4]

pe = _____

b) What are the predominant forms of nitrogen and sulfur under these conditions. [2]

N: _____ S: _____

c) Provide the oxidation states and phase (aqueous or solid) for arsenic and lead under these conditions. [2]

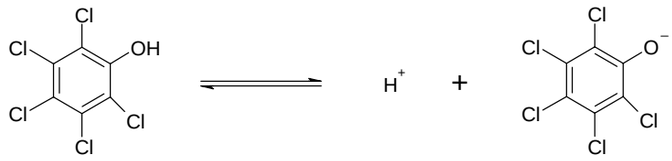
As: _____, _____ Pb: _____, _____

d) Derive the equation of the CrO_4^{2-}/Cr^{3+} boundary, given that E^o for this couple is 1.514 V. [4]

9. Lead solder on copper plumbing has been suggested as a possible source of low levels of lead (II) ions in drinking water. Using the standard reduction tables and the Nernst equation, comment on the possibility of Pb^{2+} being present at or above the MAC of 10. ppb, if the water in contact with Pb(s) contains Cu^{2+} at 0.10 ppm (ignore Cu^{+} ions). [5]

Concentration of Pb^{2+}: _____ ppb

10. Pentachlorophenol (PCP) is 99.7% ionized (PCP) in the human body, which is buffered at pH = 7.41 (i.e., $\alpha_{PCP^-} = 0.997$).



PCP PCP-

a) Calculate the pK_a for PCP. [4]
b) Sketch a labeled pH speciation diagram for pentachlorophenol. [2]

K_a: _____

diagram:

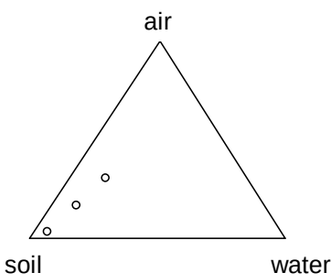
11. Draw the *structure* and briefly describe the *environmental significance* of TWO of the following. [6]

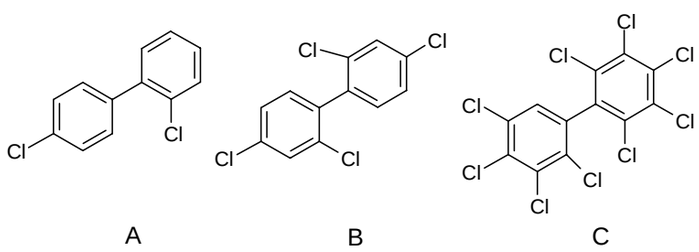
a) nitrilotriacetate (NTA)

b) sodium tripolyphosphate (STP)

c) any surfactant molecule

12. Three PCB congeners have been investigated and placed on the following diagram based on their physical properties, such as K_{ow}, K_{oc} and K_H.





a) Define the term congener. [1]

b) Label the points on the diagram as A, B or C. [1]

c) Define and provide the environmental significance of any one of the partition co-efficients listed above. [2]

d) Why are lipophilic xenobiotics generally more harmful and pervasive than hydrophilic xenobiotics in the environment? [2]

Part B: Do ONE Question on This Page (answer in Exam Booklet)

13 A) Calcium hypochlorite ($Ca(OCl)_2$ is a convenient alternative to the use of chlorine gas for small scale treatment systems. What volume of a 1.0 **M** solution of $Ca(OCl)_2$ is required to give a 1.0 ppm residual chlorine in a 80,000 L reservoir with a known chlorine demand of 0.2 ppm. [6]

$Ca(OCl)_2 + 2\ H_2O \rightarrow Ca(OH)_2 + 2\ HOCl$

OR

13 B) A soil containing both $MnO_2(s)$ and $Fe(OH)_3(s)$ is in contact with groundwater with a pH = 7.0. From the supplied reduction potentials, calculate the concentration of Fe^{2+} if $[Mn^{2+}] = 1.0 \times 10^{-5}$ M. How would your answer (above) change if the pH = 5.0 [6]

Part B: Do ONE Question on This Page (answer in Exam Booklet)

14A) A woodwaste leachate sample has a Fe(II) concentration of 20 mg/L and a dissolved organic matter concentration of 50 mg/L. Using the typical value for the concentration of carboxylate ions of 5 mmol per g of DOM and the formation constant given below, calculate the fraction of iron complexed to the dissolved organic matter at pH 5. How would you expect your answer to change if the actual pH of the leachate were 7 rather than 5? Explain. [6]

OR

14B) Draw the structure of a typical fulvic acid molecule with approximate molar mass of ~500 g/mol. Illustrate functional groups that may become involved in each of the following. [6]
i) the complexation of metal ions
ii) the formation of trihalomethanes
iii) hydrogen-bonding with a persistent organic pollutant

Part B: Do ONE Question on This Page

15A) Increased nutrient flows into shallow coastal marine environments (such as the Gulf of Mexico and the Baltic Sea) have resulted in wide scale anoxia (dead zones). Discuss this phenomena in terms the solubility, redox behaviour and physical processes in terms of the following. [8]

a) During high run-off in winter/early spring, the O_2 concentration reaches an annual maximum. The nitrate and phosphorous concentrations are high and phosphorus is being removed by adsorptive sedimentation on insoluble metal oxides.

b) During late summer, the O_2 concentrations drop dramatically along with the nitrate levels.

c) During anaerobic periods, phosphates are released to the water column to be taken up by microorganisms; during aerobic periods, phosphates are returned to the sediments.

d) What class of molecules is responsible for most of the reducing power in aqueous environments? What water quality parameter is a measure of reducing power?

OR

15B) A cementation reaction has employed iron metal to remove Cd^{2+} present at a concentration of 350 mg/L from 4.5×10^6 L of wastewater. Give the balanced chemical equation, calculate the equilbrium constant and determine the mass of iron consumed in removing all the Cd^{2+} ions. [8]