

No outside paper is allowed. Use the reverse side of your answer paper as scratch. Write your questions **clearly** and using the **correct units** to get full points. For multiple choice and similar problems, show the calculation on the reverse page to get partial points. The last page contains a periodic table and some important constants. $E = E^0 - (R T / n F) \ln (Q)$; $\ln(N_t / N_0) = -k t$; $E = mc^2$). Total points = $28 + 80 + 10 = 118$.

ESSAY. Write your answer in the space provided or on a separate sheet of paper.

- 1) Solution of a sparingly soluble salt A_xB has concentration of $A^+ = 1.3 \times 10^{-4} M$ in equilibrium with solid salt. If K_{sp} of the salt is 1.1×10^{-12} , calculate the value of x (6 pts).

$$A_xB \rightarrow xA^+ + B^-$$

$$K_{sp} = [A^+]^x [B^-]$$

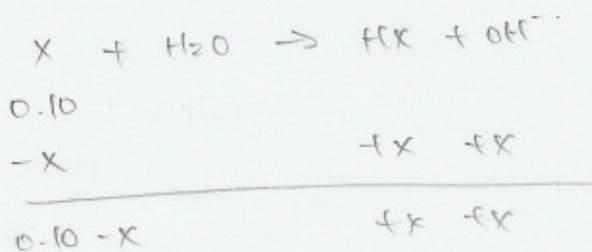
$$K_{sp} = [1.3 \times 10^{-4}]^x [6.5 \times 10^{-5}]$$

$$x \log(1.3 \times 10^{-4}) = \frac{K_{sp}}{(6.5 \times 10^{-5} M)}$$

$$x = 1.9998 \approx 2$$

- 2) Pyridine, a weak base, has $pK_b = 8.77$. What is the pH of a 0.10 M pyridine solution? (6 pts).

$$K_b = 10^{-8.77} = 1.7 \times 10^{-9}$$



$$\frac{x^2}{0.10 - x} = 1.7 \times 10^{-9}$$

$$\frac{x^2}{0.10} = 1.7 \times 10^{-9}$$

$$x = 1.3 \times 10^{-5} M$$

$$[OH^-] = 1.3 \times 10^{-5} M$$

$$pOH = -\log(1.3 \times 10^{-5})$$

$$= 4.88$$

$$pH = 14.00 - 4.88$$

$$= 9.12$$

$P_{H_2} = 1.0 \text{ atm}$

3) If voltage of a Zn - H⁺ cell is 0.45 V at 25°C, when [Zn²⁺] = 1.0 M and partial pressure of hydrogen = 1.0 atm, what is the concentration of H⁺? In the expression of Q, the quotient, for the concentration of the gaseous hydrogen, you use the partial pressure. And E⁰ for Zn²⁺ + 2e⁻ → Zn (s) is -0.76 V (8 pts).

$$E = E^0 - \frac{RT}{nF} \ln Q$$

$$\frac{RT}{nF} \ln Q = E^0 - E$$

$$(0.0128) \ln Q = +0.76 \text{ V} - 0.45 \text{ V}$$

$$\ln Q = 3.3 \times 10^{10}$$

$$Zn + 2H^+ \rightarrow Zn^{2+} + H_2(g)$$

$$E_{cell} = E_{red} - E_{ox}$$

$$0 = 0.76$$

$$= 0.76$$

$$\frac{[Zn^{2+}][H_2]}{[H^+]^2} = 3.3 \times 10^{10}$$

$$[H^+] = \sqrt{\frac{(1.0 \text{ M})(1.0 \text{ atm})}{3.3 \times 10^{10}}}$$

$$= 5.5 \times 10^{-6} \text{ M}$$

4) How much energy is lost / gained when a mole of cobalt-60 undergoes beta decay: ⁶⁰₂₇Co → ⁰₋₁e + ⁶⁰₂₈Ni? The mass of ⁶⁰₂₇Co atom, 59.933819 amu and mass of ⁶⁰₂₈Ni atom, 59.930788 amu and mass of an ⁰₋₁e is 5.4858 x 10⁻⁴ amu. Hint: an atom consists of the nucleus and the electrons (8 pts).

mass ⁶⁰₂₇Co nucleus = 59.919007 = 59.933819 - (27)(5.4858 x 10⁻⁴)

mass of ⁶⁰₂₈Ni nucleus = 59.915428 = 59.930788 - (28)(5.4858 x 10⁻⁴)

$$\Delta m = (1 \text{ electron} + \text{mass of } ^{60}_{28}\text{Ni}) - \text{mass of } ^{60}_{27}\text{Co} = 5.4858 \times 10^{-4} + 59.915428 - 59.919007 = -0.00303042 \text{ amu}$$

$$\Delta m = \left(-0.00303042 \text{ amu} \right) \times \frac{1.66 \times 10^{-27} \text{ kg}}{1 \text{ amu}}$$

$$= 5.032 \times 10^{-30} \text{ kg}$$

When one mole of Cobalt-60 decays, $\Delta m = -0.003031 \text{ g} = -0.003031 \times 10^{-3} \text{ kg}$

$$E = \Delta m c^2 = 0.003031 \times 10^{-3} \times (3.0 \times 10^8)^2 \text{ J}$$

$$= 4.520 \times 10^{13} \text{ J}$$

(1 amu = 1.66 x 10⁻²⁷ kg)

(1 mole weighs 6.022 amu)

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question (4 pts each).

Consider the following table of K_{sp} values.

Name	Formula	K_{sp}
Cadmium carbonate	$CdCO_3$	5.2×10^{-12}
Cadmium hydroxide	$Cd(OH)_2$	2.5×10^{-14}
Calcium fluoride	CaF_2	3.9×10^{-11}
Silver iodide	AgI	8.3×10^{-17}
Zinc carbonate	$ZnCO_3$	1.4×10^{-11}

5) Which compound listed below has the greatest molar solubility in water? *largest*

- A) $Cd(OH)_2$ B) $CdCO_3$ C) AgI D) CaF_2 E) $ZnCO_3$

5) ~~E~~ D

6) The pH of a solution prepared by mixing 45 mL of 0.183 M KOH and 65 mL of 0.145 M HCl is _____.

- A) 70.145 B) 1.31 C) 0.74 D) 1.97 E) 2.92

6) ~~E~~ D

7) Which one of the following pairs cannot be mixed together to form a buffer solution?

- A) $RbOH, HBr$
 B) KOH, HF ✗
 C) H_3PO_4, KH_2PO_4
 D) NH_3, NH_4Cl
 E) $NaC_2H_3O_2, HCl$ ($C_2H_3O_2^-$ = acetate)

7) ~~E~~ A

8) Which of the following is not a chelating agent?

- A) EDTA ✓
 B) ethylenediamine ✓
 C) oxalate anion ✓
 D) chloride anion
 E) porphine ✓

8) D

9) How many bonds can ethylenediamine form to a metal ion?

- A) 1 B) 2 C) 4 D) 6 E) 3

9) B

10) Complexes containing metals with which one of the following electron configurations are usually colorless?

- A) d^5 B) d^{10} C) d^1 D) d^8 E) d^2

10) B

11) Which one of the following complex ions will be paramagnetic?

- A) $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ (low spin) \times
- B) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ (low spin) \times
- C) $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$ (low spin) \times
- D) $[\text{Zn}(\text{H}_2\text{O})_4]^{2+}$ \rightarrow weak
- E) $[\text{Zn}(\text{NH}_3)_4]^{2+}$ \rightarrow weak

got magnetism
must be high spin

11) ~~D~~ A

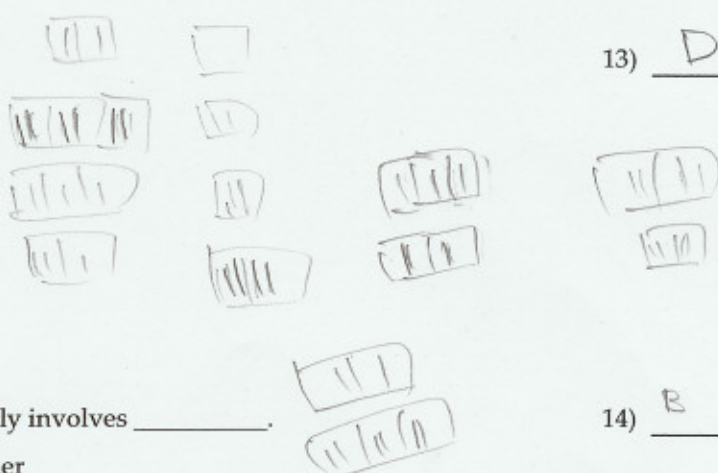
12) As a polymer becomes more crystalline, _____.

- A) its density decreases \times
- B) its yield stress decreases \times
- C) its melting point decreases \times
- D) its stiffness decreases \times
- E) none of the above are correct

12) E

13) Which complex below has 2 unpaired electrons?

- A) low-spin octahedral $[\text{Fe}(\text{CN})_6]^{3-}$ d^5 \times
- B) square-planar $[\text{Ni}(\text{CN})_4]^{2-}$ d^8
- C) tetrahedral $[\text{FeI}_4]^{2-}$ d^6 \checkmark
- D) octahedral $[\text{Ni}(\text{NH}_3)_6]^{2+}$ d^8 \times
- E) tetrahedral $[\text{CoCl}_4]^{2-}$ d^7 \times



13) D

14) The formation of a condensation polymer generally involves _____.

- A) the mixing of sulfur with an addition polymer
- B) the elimination of a small molecule H_2O
- C) the vaporization of a plasticizer
- D) the formation of significant crosslinking
- E) the addition of a plasticizer

$$S = \frac{C}{A} \rightarrow \frac{4}{26} = 0.1538$$

14) B

15) How many seconds are required to produce 4.00 g of aluminum metal from the electrolysis of molten AlCl_3 with an electrical current of 12.0 A?

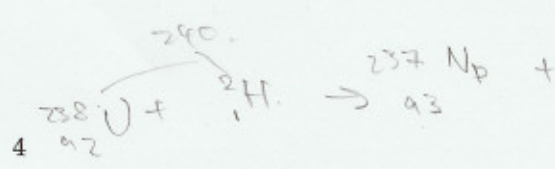
- A) 1.19×10^3
- B) 27.0
- C) 3.57×10^3
- D) 9.00
- E) 2.90×10^5

$$C = A \times S$$

15) A/C

16) Bombardment of uranium-238 with a deuteron (hydrogen-2) generates neptunium-237 and _____ neutrons.

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



16) C

17) The empirical formula of an addition polymer _____.

17) D

- A) is the same as that of the monomer from which it is formed except that 2 H and 1 C have been subtracted
- B) is the same as that of the monomer from which it is formed except that 2 H and 1 C have been added
- C) is the same as that of the monomer from which it is formed except that 2 H and 1 O have been subtracted
- D) is the same as that of the monomer from which it is formed
- E) is the same as that of the monomer from which it is formed except that 2 H and 1 O have been added

18) Calculate the percent ionization of nitrous acid in a solution that is 0.249 M in nitrous acid. The acid dissociation constant of nitrous acid is 4.50×10^{-4} .

18) E

- A) 1.12×10^{-4}
- B) 5.53
- C) 0.342
- D) 0.0450
- E) 4.25

$$\frac{[H^+][A^-]}{[HA]} = 4.5 \times 10^{-4}$$

19) Which transformation could take place at the anode of an electrochemical cell?

19) F

- A) $HAsO_2$ to As
- B) $Cr_2O_7^{2-} \rightarrow Cr^{2+}$ ✗
- C) F_2 to F^- ✗
- D) O_2 to H_2O ✗
- E) None of the above could take place at the anode.

oxidation

$$-b \pm \sqrt{b^2 + 4ab}$$

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

20) B



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

$$2Fe^{3+} + 2e^- \rightarrow 2Fe^{2+}$$

$$CN^- + H_2O \rightarrow CNO^- + 2H^+ + 2e^-$$

21) The more _____ the value of E°_{red} , the greater the driving force for reduction.

21) D

- A) exothermic
- B) extensive
- C) negative
- D) positive ✓
- E) endothermic

22) Cesium-137 undergoes beta decay and has a half-life of 30 years. How many beta particles are emitted by a 14.0-g sample of cesium-137 in three minutes? 22) ~~D~~

- A) 6.1×10^{13} B) 1.3×10^{-8} C) 6.2×10^{22} D) 8.1×10^{15} E) 8.4×10^{15}

Table 20.2

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

23) Which of the following reactions will occur spontaneously as written? 23) C

- A) $\text{Sn}^{2+}(\text{aq}) + \text{Fe}^{2+}(\text{s}) \rightarrow \text{Sn}^{4+}(\text{aq}) + \text{Fe}^{3+}(\text{aq})$ X
 B) $2\text{Cr}^{3+}(\text{aq}) + 3\text{Sn}^{2+}(\text{aq}) \rightarrow 3\text{Sn}^{4+}(\text{aq}) + 2\text{Cr}(\text{s})$ X
 C) $2\text{Cr}(\text{s}) + 3\text{Fe}^{2+}(\text{s}) \rightarrow 3\text{Fe}(\text{s}) + 2\text{Cr}^{3+}(\text{aq})$ ✓
 D) $3\text{Fe}^{2+}(\text{aq}) + \text{Cr}^{3+}(\text{aq}) \rightarrow \text{Cr}(\text{s}) + 3\text{Fe}^{3+}(\text{aq})$
 E) $\text{Sn}^{4+}(\text{aq}) + \text{Fe}^{2+}(\text{s}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Fe}(\text{s})$ X

6.34×10^{22}

$A = A_0 e^{-kt}$

$E_{\text{red}} - E_{\text{ox}}$

$-0.440 - (-0.154)$
 $-0.74 - 0.154$
 $-0.440 - (-0.74)$
 $0.74 - (-0.440)$
 $+0.154 - (-0.440)$

24) Which one of the following can be done to shorten the half-life of the radioactive decay of uranium-238? 24) E

- A) freeze it
 B) convert it to UF_6
 C) heat it
 D) oxidize it to the +2 oxidation state
 E) none of the above

TRUE/FALSE. Write 'T' if the statement is true and 'F' if the statement is false (2 pts each).

25) E°_{cell} is the difference between the reduction potential at the cathode and the potential at the anode. 25) T

26) Polyethylene is formed by a condensation reaction. X 26) F

27) Vulcanization involves heating rubber with sulfur dioxide to produce a thermosetting polymer. 27) ~~T~~ F

28) The extent of ionization of a weak electrolyte is increased by adding to the solution a strong electrolyte that has an ion in common with the weak electrolyte. 28) F

29) The standard reduction potential of X is 1.23 V and that of Y is -0.44 V therefore X is oxidized by Y. 29) F

↓
reduced

↑
oxidised