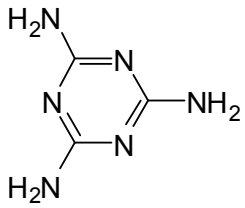
1. The compound *melamine* has garnered much attention over the last couple years, as it is the spotlight of the tainted milk scandal in China. The relatively high nitrogen content of *melamine* skews the results of protein analyses. What is the mass percent of nitrogen in *melamine*?

A) 66.7
B) 65.1
C) 63.6
D) 96.9
E) 69.9



melamine

$C_3H_6N_6$

126.12 g/mol

N x 6 = 84

2. At room temperature, *melamine* is a solid. At 350 °C, solid *melamine* sublimes with a heat of sublimation of 121 kJ mol^{-1}. Which of the following statement(s) are correct when *melamine* is subliming at 350 °C?

1. The sublimation process is entropically driven ✓
2. It is converting from the solid phase to the gas phase ✓
3. The sublimation process is endothermic ✓

A) All statements are correct
B) 2 and 3 only
C) 1 and 2 only
D) 2 only
E) 3 only

sublimation (and evaporation) are endothermic but they proceed because of the large entropy increase

3. Which one of the following statements is correct?

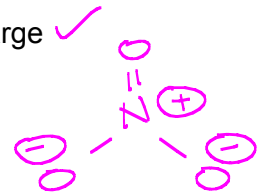
A) Nitrate (NO_3^-) contains a nitrogen atom with a positive formal charge ✓

B) BF_3 is a polar molecule × trig. planar

C) Ground-state Fe^{3+} has 3 unpaired electrons × 5

D) The carbon atoms of graphite are sp^3-hybridized × sp^2

E) Solar energy is formed predominantly by nuclear fission × fusion



4. When the compound shown below is in its most-stable conformation, exactly how many of the methyl (CH_3) groups are in the equatorial position?

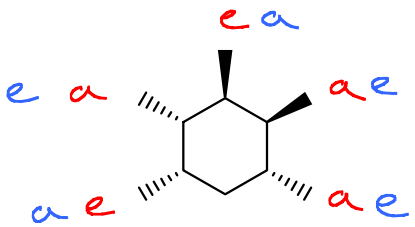
A) 3

B) 5

C) 2

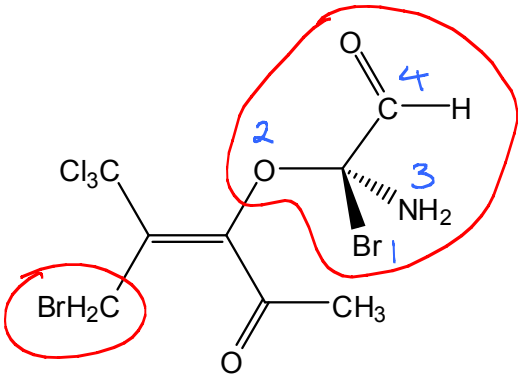
D) 4

E) 1



option 1
option 2

5. Which one of A – E correctly describes the stereochemical configuration of the compound shown below?



A) *E, S*

B) *E, R*

C) *Z, R*

D) *Z, S*

E) achiral

6. Which of the following statement(s) is/are correct in describing infrared (IR) light and UV-visible light, and their spectroscopic applications?

1. The absorption of IR light can be used to identify functional groups
2. The absorption of UV-visible light causes an electron to be excited into a higher-energy orbital
3. The wavelength of IR light is longer than that of visible light

A) All statements are correct

B) 2 and 3 only

C) 1 and 2 only

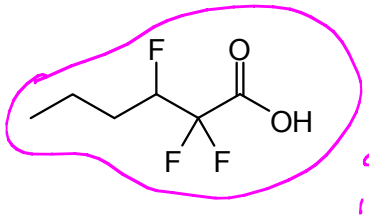
D) 1 and 3 only

E) 3 only

7. Which one of the following compounds is the most acidic (lowest pK_a)?

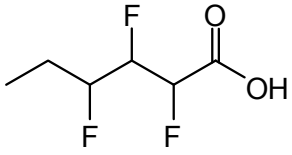
ie most-stable conj. base

A)

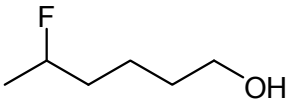


COO⊖ resonance and most induction

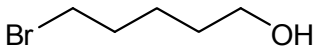
B)



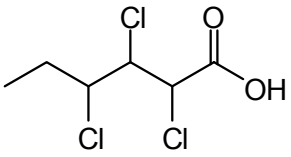
C)



D)



E)

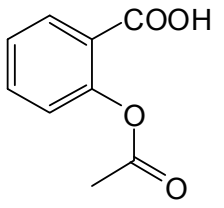


8. Acetylsalicylic acid (K_a = 3.3 × 10^{-4}) is the active ingredient in aspirin. What is the pH of a 0.10 M solution of acetylsalicylic acid?

A) 2.24
B) 2.74
C) 5.48
D) 2.15
E) 4.48

$K_a = \frac{[H^+][A^-]}{[HA]}$

$3.3 \times 10^{-4} = \frac{(x)(x)}{(.1-x)}$



acetylsalicylic acid

$x = [H^+] \Rightarrow$ find pH

9. 15 g of NaOH are dissolved in 100 mL of water and then combined with 500 mL of 1.5 M acetylsalicylic acid ($K_a = 3.3 \times 10^{-4}$). What is the pH of the resulting solution?

0.75 mol HA
0.375 mol OH^-

0.375 mol HA
0.375 mol A^-

when equal, pH = pKa

A) 3.48
B) 1.65
C) 2.88
D) 7.00
E) 3.78

10. A 0.0010 M solution of $Ba(NO_3)_2$ is added gradually to 200 mL of 0.040 M NaF. Precipitation of BaF_2 begins after 35 mL of $Ba(NO_3)_2$ have been added. What is the K_{sp} for BaF_2?

from review problems

A) 1.7×10^{-7}
B) 1.6×10^{-6}
C) 6.4×10^{-6}
D) 6.9×10^{-7}
E) 1.0×10^{-5}

11. $Ca(OH)_2$ is used to treat lakes and soils that have been affected by acid rain. If its K_{sp} is 1.4×10^{-6}, what is the pH of a saturated solution of $Ca(OH)_2$?

A) 12.2
B) 11.9
C) 11.1
D) 10.8
E) 7.0

$Ca(OH)_2 \rightleftharpoons Ca^{2+} + 2\,OH^-$

$x \qquad 2x$

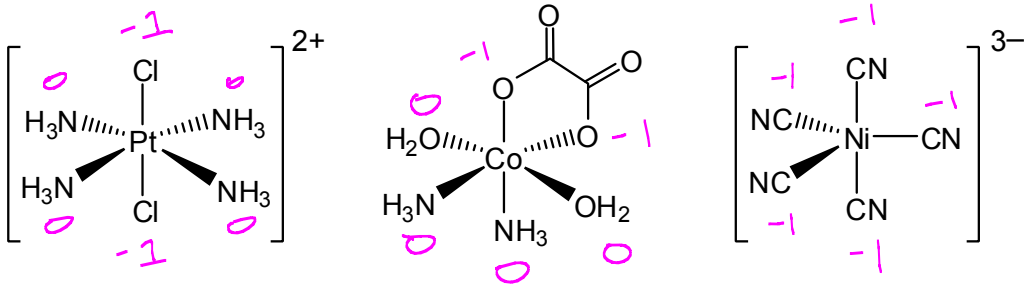
$K_{sp} = [Ca^{2+}][OH^-]^2$

$= (x)(2x)^2 \quad$ i.e. $2x = [OH^-]$

$= 4x^3$

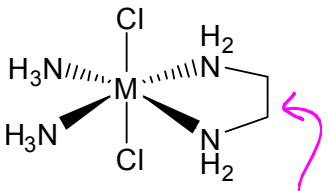
find x, find $2x$, find pOH $\Rightarrow$ pH

12. Which one of A – E correctly describes the oxidation state (oxidation number) of the transition metals in the following complexes?



	Pt	Co	Ni
A)	+4	+2	+2
B)	+2	0	−3
C)	+3	+3	+2
D)	+2	+2	−2
E)	+4	+1	+2

13. Which of the following statement(s) is/are correct about the transition metal complex shown on the right?



bidentate and chelating

1. It contains a bidentate ligand ✓
2. It contains a chelating ligand ✓
3. Stereoisomers are possible for the complex ✓

cis/trans Cl groups

A) All statements are correct
B) 2 and 3 only
C) 1 and 2 only
D) 1 and 3 only
E) 3 only

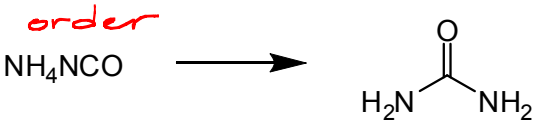
14. Acetaminophen, the active ingredient in Tylenol, is metabolized via first-order kinetics and has a half-life of two hours. If a 1000 mg dose is consumed, how many mg of acetaminophen remain in the body after 3.25 hours?

from review problems

A) 324
B) 676
C) 188
D) 381
E) Cannot be determined without knowing the molar mass of acetaminophen

15. A kinetic study was performed on the reaction below by measuring the concentration of NH_4NCO in the solution at various times. A plot of $[NH_4NCO]^{-1}$ versus time (in hours) resulted in a straight line with a slope of 0.68 mol^{-1} L h^{-1}.

2nd order



k

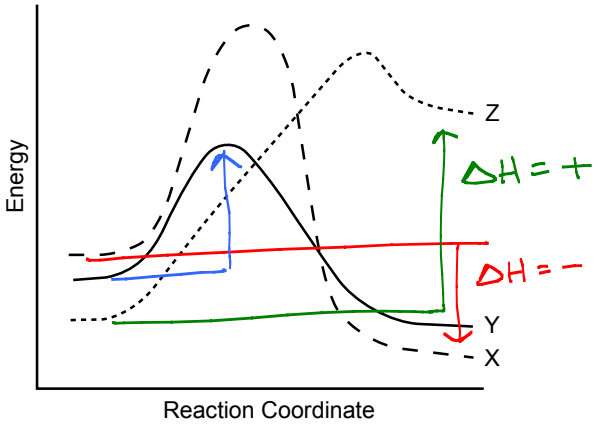
What is the rate of the reaction when the concentration of NH_4NCO is 0.50 M?

Rate = k (.5)²

A) 0.17 M h^{-1}
B) 0.34 M h^{-1}
C) 2.72 M h^{-1}
D) 0.74 M h^{-1}
E) 1.36 M h^{-1}

16. The reaction coordinates for reactions X, Y, and Z are below. Which statement(s) is/are correct? Assume all three reactions are at the same temperature.

1. Reaction X is exothermic ✓
2. Reaction Y has the smallest activation energy ✓
3. Reaction Z is endothermic ✓



A) All statements are correct
B) 2 and 3 only
C) 1 only
D) 2 only
E) 1 and 3 only

17. A general rule of thumb is that the rate constant for any given reaction doubles with each temperature increase of 10 °C. For this to be true when going from 25 °C to 35 °C, what must be the activation energy of the reaction?

A) 53 kJ mol^{-1}
B) 153 kJ mol^{-1}
C) 106 kJ mol^{-1}
D) 3.6 kJ mol^{-1}
E) 0.5 kJ mol^{-1}

$$\ln\left(\frac{\text{rate}_2}{\text{rate}_1}\right) = \frac{Ea}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$\frac{\text{rate}_2}{\text{rate}_1} = 2$; $T_1 = 298.15$; $T_2 = 308.15$; $R = .008314\ \text{kJ mol}^{-1}\ \text{K}^{-1}$

18. Suppose an enzyme reduces the activation energy for a reaction from 100 kJ mol^{-1} to 60.0 kJ mol^{-1}. If the reaction is occurring at 310 K, by what factor does the enzyme increase the rate of the reaction?

A) 5.50×10^{6}
B) 15.5
C) 1.02
D) 7.09×10^{16}
E) 1.29×10^{10}

$\Delta Ea = 40000\ \text{J mol}^{-1}$

$$\ln(\text{factor}) = \frac{\Delta Ea}{RT}$$

$R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$

19. In the Redox experiment, Fe^{2+} was titrated with MnO_4^- under acidic conditions. The products are water, Fe^{3+}, and Mn^{2+}. Which statement is NOT correct?

A) The reaction is a disproportionation reaction ✓
B) Eight moles of H^+ are consumed for every mole of MnO_4^- used
C) MnO_4^- is the oxidizing agent
D) Five moles of Fe^{2+} are oxidized for every mole of MnO_4^- used
E) Four moles of H_2O are formed for every mole of MnO_4^- used

$MnO_4^- + Fe^{2+} \rightarrow H_2O + Fe^{3+} + Mn^{2+}$

$(Fe^{2+} \rightarrow Fe^{3+} + e^-) \times 5$

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$

20. Which of metals Ag, Fe, Mn, and Pb will dissolve in 1.0 M Ni^{2+}?

A) Fe and Mn only Have lower $E°_{red}$ than Ni^{2+}
B) Fe, Mn, and Pb
C) Pb and Ag only
D) Mn only
E) Ag only

H_2O, Na^+, Cl^-

21. In the electrolysis of aqueous sodium chloride (NaCl), what are the products formed at the cathode?

reduction end

A) Hydroxide ions and hydrogen gas
B) Sodium metal and chlorine gas
C) Sodium metal and hydroxide ions
D) Hydrogen gas and chlorine gas
E) Chlorine gas and hydroxide ions

H_2O reduced instead of Na^+

22. The net reaction that occurs in an alkaline battery is shown below. If the battery provides a current of 0.40 amperes for 12 hours, how many grams of zinc are consumed?

$$\overset{0}{Zn}(s) + 2MnO_2(s) \rightarrow \overset{+2}{Zn}O(s) + Mn_2O_3(s)$$

2 e⁻ process

A) 5.86
B) 2.92
C) 14.6
D) 7.28
E) 11.7

$0.40\ \frac{C}{s} \times 12\ h \times 3600\ \frac{s}{h} =$

17280 C

$$\frac{17280\ C}{96485\ C\ mol^{-1}} = 0.179\ mol\ e^-$$

$\therefore$ 0.0895 mol Zn needed = 5.86 g

23. A solution has an absorbance of 0.260 at a certain wavelength when measured in a sample holder with a path length of 1.00 cm. If 1.00 mL of this solution is diluted to a final volume of 10.0 mL, what is the absorbance of the new solution at the same wavelength in a sample holder with a 5.00 cm path length?

dilution reduces absorption to 1/10th, but longer cell increases by 5 so 1/2

A) 0.130
B) 0.260
C) 1.30
D) 0.520
E) 0.065

24. In the Kinetics experiment, the reaction shown below was performed. Starch was added to the reaction mixture because…

$$BrO_3^-(aq) + 6H^+(aq) + 6I^-(aq) \rightarrow Br^-(aq) + 3H_2O(l) + 3I_2(s)$$

A) It allows one of the products of the reaction to be visually detected ✓
B) It provides an energy source for the endothermic reaction to occur
C) It regulates the rate of the reaction
D) It neutralizes any excess acid that may be present
E) It acts as a source of iodide ions

Question 1

The K_{sp} of Li_2CO_3 at 25°C is 2.5×10^{-2}.

A. Write the chemical equation for the dissolving of Li_2CO_3 and its K_{sp} expression .

$Li_2CO_3 \rightleftharpoons 2\,Li^+ + CO_3^{2-}$

$K_{sp} = [Li^+]^2 [CO_3^{2-}]$

B. Calculate the solubility (moles per litre) of $Li_2CO_3(s)$ in water at 25°C.

$LiCO_3 \rightleftharpoons 2\,Li^+ + CO_3^{2-}$

$-x \qquad +2x \qquad +x$

x = amount that dissolves

$2.5 \times 10^{-2} = (2x)^2(x) = 4x^3$

$x = 0.184$ mol/L

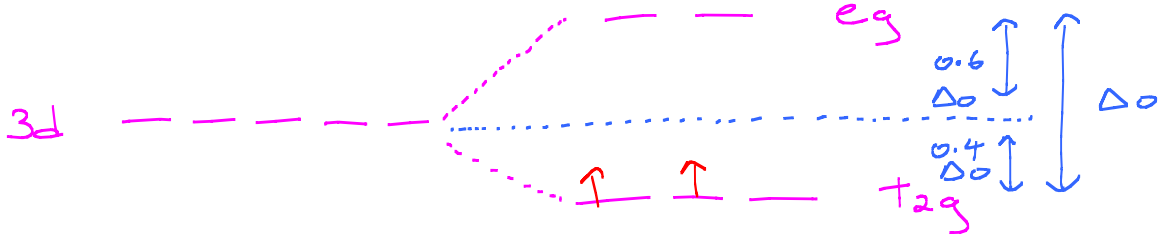
C. Explain, with the help of an equation if necessary, why Li_2CO_3 is much more soluble in a solution of hydrochloric acid than in pure water.

CO_3^{2-} is basic, so it reacts with H^+ to form HCO_3^- and H_2CO_3. More Li_2CO_3 dissolves to replenish the CO_3^{2-}.

Question 2

V^{3+} = [Ar] $4s^0$ $3d^2$

A. Draw an energy diagram to show the splitting of the five degenerate 3*d* orbitals in the octahedral complex $[V(H_2O)_6]^{3+}$ into higher and lower energies, indicating their relative energies in the complex. Show the configuration of the 3*d* electrons.

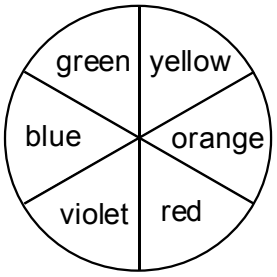


absorbs red absorbs violet

B. Transition metal complex X appears green, and complex Y appears yellow. Which complex has the largest Δ_o? Explain your reasoning. The visible spectrum and the colour wheel are provided below for reference.

violet	blue	green	yellow	orange	red

400 nm 800 nm



Y absorbs light of a shorter wavelength (higher energy), so it has the largest Δ_o

Question 3

The data below were collected at 25 °C for the reaction of nitric oxide with chlorine.

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$$

Run	[NO] (mol L^{-1})	$[Cl_2]$ (mol L^{-1})	Initial Rate (mol L^{-1} s^{-1})
i	0.0200	0.0200	7.1×10^{-5}
ii	0.0400	0.0200	2.8×10^{-4}
iii	0.0200	0.0400	1.4×10^{-4}

2x 4x

A. Using this data, determine the order of each of NO and Cl_2, and then write the complete rate law. Explain your reasoning and/or show your work.

doubling NO quadruples rate ∴ $[NO]^2$

doubling Cl_2 doubles rate ∴ $[Cl_2]^1$

$$Rate = k[NO]^2[Cl_2]$$

could also show work and division

B. What is the value of the rate constant, including units?

Choose any one of three runs.

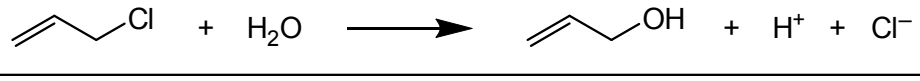
e.g. $7.1 \times 10^{-5}\ mol\ L^{-1}\ s^{-1} = k(.02\ mol\ L^{-1})^2(.02\ mol\ L^{-1})$

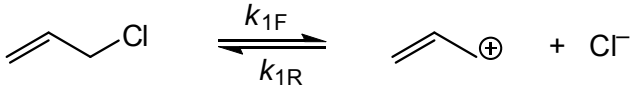
$= k(.000016\ mol^3\ L^{-3})$

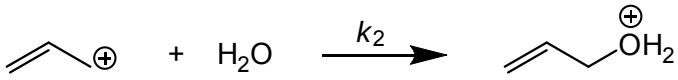
$k = 8.88\ L^2\ mol^{-2}\ s^{-1}$

Question 4

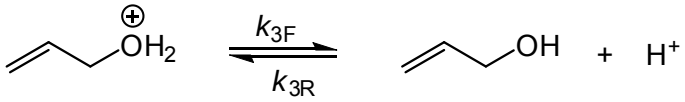
If the overall reaction in the box proceeds according to the indicated three-step mechanism, derive the rate law expected for the overall reaction.

Overall 

Step 1 (fast) 

Step 2 (slow) 

RDS

Step 3 (fast) 

Rate = k_2 [⟋⊕] [H2O]

↖ intermediate from # 1

Since eqm,

k_{1F} [⟋Cl] = k_{1R} [⟋⊕] [Cl⊖]

[⟋⊕] = $\frac{k_{1F}\,[\text{⟋Cl}]}{k_{1R}\,[Cl^{\ominus}]}$

Rate = $\frac{k_2 k_{1F}\,[\text{⟋Cl}]\,[H_2O]}{k_{1R}\,[Cl^-]}$

= $k'\,[\text{⟋Cl}]\,[H_2O]\,[Cl^{\ominus}]^{-1}$

Question 5

The redox reaction below occurs when ammonia is mixed with hypochlorite (bleach) in a **basic solution**. Balance the reaction, showing all your work.

$$NH_3 + ClO^- \rightarrow N_2H_4 + Cl^-$$

(example 12.1.5)

$2\ NH_3 \longrightarrow N_2H_4$

$2\ OH^-$ $2\ H_2O$

$2e^-$

$ClO^- \rightarrow Cl^-$

~~$2\ H_2O$~~ ~~H_2O~~

$2e^-$ $2\ OH^-$

$$2\ NH_3 + ClO^- \rightarrow N_2H_4 + Cl^- + H_2O$$

Question 6

Consider a voltaic cell with the overall reaction shown below.

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

A. Write the *cell diagram* for the reaction.

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

B. What is the E°_{cell} for this cell?

$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$ $\quad E^\circ_{ox} = .76\ V$

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $\quad E^\circ_{red} = .34\ V$

$E^\circ_{cell} = 1.10\ V$

C. What is E_{cell} when the concentration of Zn^{2+} is 0.75 M and that of Cu^{2+} is 0.50 M?

$$E_{cell} = E^\circ_{cell} - \left(\frac{RT}{nF}\right) \ln Q \qquad Q = \frac{0.75}{0.50} = 1.5$$

(or any other)

$$= 1.10 - \left(\frac{8.314 \times 298}{2 \times 96485}\right) \ln 1.5$$

$$= 1.09\ V$$