SOLUTIONS AQUINAS 2013 CHEM Stage 3 EXAM

SECTION 1 – Multiple Choice

1. a
2. c
3. c
4. b
5. a
6. b
7. a
8. b
9. d
10. d
11. b
12. b
13. c
14. a
15. d
16. b
17. a
18. d
19. d
20. b
21. b
22. a
23. c
24. c
25. c

SECTION 2 – Short Answer

1.

a.

i. Valence shell electron pair repulsion theory, is used to predict the shape of molecules based on the repulsion of pairs of electrons.

ii. CF_4 four bond pairs surround central atom therefore equal repulsion between pairs of electrons 109 tetrahedral in shape. PH_3 has lone pair closer to nucleus greater repulsion pushes bonded pairs closer together forms pyramidal shape.

b.

Pairs of substances	**Higher boiling**	**Intermolecular force responsible**

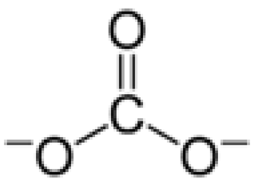
	substance	for the difference
F_2 and Cl_2	Cl_2	Dispersion
CH_2CH_2OH and $CH_3CH_2NH_2$	CH_2CH_2OH	Hydrogen bond
$CH_3(CH_2)_{10}OH$ and CH_3OH	$CH_3(CH_2)_{10}OH$	dispersion
Br_2 and ICl	ICl	Dipole-dipole

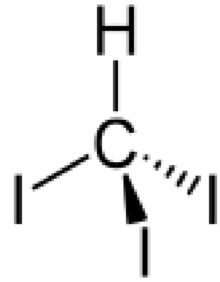
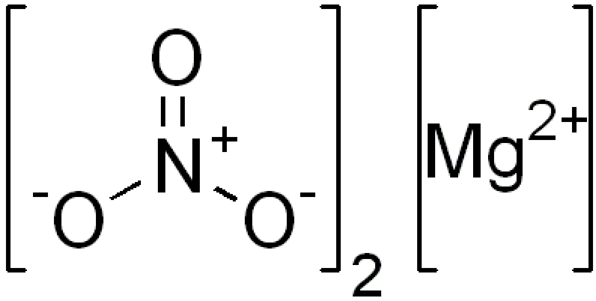
c.

i. Metals are bonded with positive metal ions and negative delocalised electrons If hit with hammer, metal ions are able to move (Indent) but still not repel each other due to the free delocalised electrons between them which reduce repulsion Diamond and glass – are made from C and SiO_2 respectively in a network lattice which is very strong but when it is hit with hammer the lattice is disrupted which will causes the particles to break apart and shatter

ii. The intermolecular forces of attraction between the water molecules and the grease molecules are weaker than the hydrogen bonds which hold water molecules together. On the other hand the intermolecular forces between the methylated spirit molecules and the grease molecules are stronger than the intermolecular forces between the grease molecules or between the methylated spirit molecules. Dispersion forces between the ethanol and the grease molecules provides enough energy to break the attraction forces between the grease molecules.

d.

Species	Electron Dot Structure (showing all valence shell electrons)	Shape (sketch or name)
CO_3^{2-}		Triagonal planar (although double bond does have greater repulsion

CHI_3		tetrahedral
$Mg(NO_3)_2$		Nitrate ion is triagonal planar but linear with Mg

2.

a.

310x $1.15*10^6 = 3.56*10^8$g x 24 = $8.544*10^9$ / 32 = $2.67*10^8$ O_2 moles each day
PV=nRT
101.3 x V = $2.67x10^8$ x 8.315x 293
V = 6430447933 litres of oxygen
Volume of air = x 100/21 = $3.062*10^{10}$ litres of air

b.

$1.55*10^4$ x 680 = n x 8.315 x 293
4326.24 = n in each cylinder
Total volume of O_2 produced each hour = $1.1140625*10^7$/4326.24 = 2575. cylinders of O_2

OR

310 x $1.5*10^6$ = 3.565 $*10^8$ O_2 p/hr / Mr(32) = 1.14 x 10^7 mol
PV= nRT V = 1.75 *106 / 680 = 2572.86 cylinders

3.

a.

NaCl solution: n(NaCl) = 0.256 × 0.200 =0.05120 mol = $n(Na^+)$
Na_2SO_4 solution: $n(Na_2SO_4)$ = 0.166 × 0.150 = 0.02490
$n(Na^+)$ = 2 × 0.02490 = 0.04980 mol
total amount of Na^+ = 0.0512 + 0.04980 = 0.101mol

$c(Na^+)$ = = 0.29 mol L^{-1}

b.

amount of Cl_2

$n = \frac{125 \times 0.280}{8.314 \times 297.1}$ = 0.01417 mol

amount of Fe^{2+} $n(FeSO_4)$ = 0.396 × 0.140 = 0.05544 mol

= $n(Fe^{2+})$

From the balanced equation

1 mol of Cl_2 reacts with 2 mol of Fe^{2+}

so 0.014 17 mol of Cl_2 will react with 2 × 0.014 17 = 0.028 34 mol of Fe^{2+}

but there is 0.055 44 mol of Fe^{2+} present in the mixture, so Fe^{2+} is in excess

From balanced equation

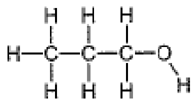
1 mol of Cl_2 will form 2 mol of Fe^{3+}

so 0.014 17 mol of Cl_2 will form 2 × 0.01417 = 0.028 34 mol of Fe^{3+}

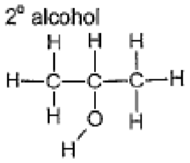
$c(Fe^{3+})$ = = 0.202 mol

4.

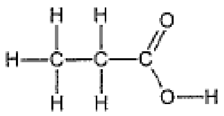
(a) 1° alcohol



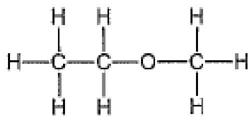
2° alcohol



(b)



(c)



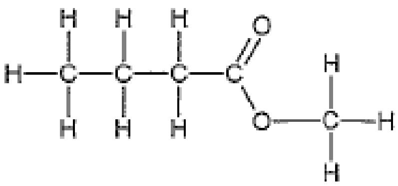
(d) **Oxidation half reaction:** $CH_3CH_2CHO + H_2O \rightarrow CH_3CH_2COOH + 2H^+ + 2e^-$

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

Redox reaction: $5CH_3CH_2CHO + 2MnO_4^- + 6H^+ \rightarrow 5CH_3CH_2COOH + 3H_2O + 2Mn^{2+}$

5.

(a) (i)



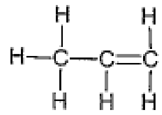
(ii) Use butanoic acid and methanol. [Sulfuric acid is a catalyst for this

(b) The unbranched carboxylic acid isomer is pentanoic acid.

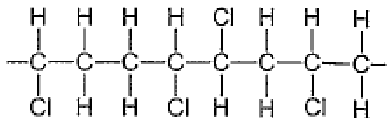
6.

(a) Addition polymerisation.

(b) A monomer is a small molecule capable of chemically combining with other small molecules so producing a very large molecule known as a polymer. In this example the monomer is propene (see structural formula at right). Propene molecules combine with each other by the elimination of the double bond. This results in the polymer structure shown.



(c)



7.

a. Decrease in forward rxn due to AgCl ppt forming and reducing conc of Ag+
b. Decrease in forward rxn more solid dissociates into soln
c. No change as saturated soln
d. Exothermic reaction
   Labels on both axis
   Ea and delta H labelled
   Reactants and Products

8.

a. PCl3 + Cl2 ←→ PCl5
b. Reaches equilibrium by Conc of PCl3 and Cl2 decreases as creates PCl5. PCl5 conc increases
c. Increase in conc of Cl2 by adding more Cl2 to reaction
d. At t = 17 increase in conc of Cl2 causes reaction to move to right to reduce stress by using up Cl2 in doing so it uses up PCl3 (lowering its conc) and creates more PCl5 (increasing its conc)
e. Increase in pressure causes increase in the concentration of each of the reactants and products
f. Works to reduce the stress by reaction mixture moving to right to side with least number of molecules as will reduce the pressure in the system. Reduces conc of Cl2 and PCl3 increases conc of PCl5
g. Reaction is heated and as reaction produces heat in forward reaction, equilibrium moves to left increasing conc of PCl3 and Cl2 and reduces conc of PCl5

9.

a. $NaHCO_{3(s)} + H^+ \rightarrow Na^+_{(aq)} + CO_{2(g)} + H_2O_{(l)}$
b. $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Section 3 – Extended Answer

Question 10

When copper (II) sulphate is dissolved in water a blue coloured solution of $Cu^{2+}_{(aq)}$ ions are formed and when treated with excess concentrated ammonia solution the initial precipitate of copper hydroxide dissolves to give a deep blue solution. When ethanol is added to the solution, deep blue crystals precipitate. When the solution is filtered the crystals smell of ammonia, and an unstable salt with the formula $Cu(NH_3)xSO_4.yH_2O$ has been formed.

(a) When 1.4009g of the unstable salt is heated at 300℃, the salt decomposes and the ammonia is driven off. The ammonia that is produced is captured and found to occupy 539.1mL at 250℃ and 104.5 kPa. Calculate the number of moles of ammonia in the 1.4009g sample of the complex salt.

[2M]

moles of ammonia – PV=nRT

104.5 x 0.5391 = n x 8.315 x 523.1

$n = \frac{56.33595}{4348.745} = 0.0130$ moles NH3

(b) Calculate the mass of the ammonia in the 1.4009g sample.

[2M]

moles x Mr = 0.01295 x 17.034 = 0.221 g

(c) Another 1.4009g sample of the unstable salt is heated at 300℃ driving all off the ammonia and water leaving only 0.9055g of copper(II) sulphate behind. Calculate the mass of water in a 1.4009g sample of the unstable salt.

[2M]

0.9055+ 0.2205903 = 1.126

1.4009 – 1.1260903 = 0.275g H2O

(d) Calculate the number of moles of water in a 1.4009g sample of the unstable salt. [1M]

0.2748097 / 18.016 = 0.0153 moles H2O

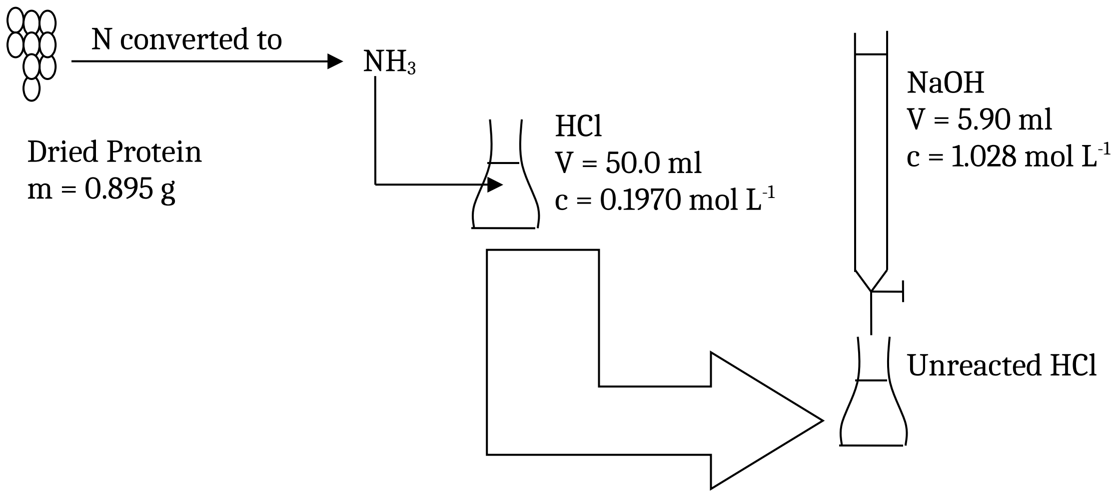
(e) Calculate the number of moles of copper (II) sulphate in the 0.90551g sample of copper sulphate.

[1M]

Mr = 159.61

Moles = 0.90551/159.61 = 0.00567 moles Cu(II) SO_4

Question 11



n(NaOH) = c x V = 1.028 x 0.00590 = 6.065 x 10^{-3} mol **(1)**

$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$ **(1)**

n(unreacted HCl) = n(NaOH) = 6.065 x 10^{-3} mol **(1)**

n(HCl before reaction) = c x V = 0.1970 x 0.050 = 9.850 x 10^{-3} mol **(1)**

n(HCl reacting with NH_3) = n(HCl before reaction) - n(unreacted HCl)
= (9.850 x 10^{-3}) – (6.065 x 10^{-3})
= 3.785 x 10^{-3} mol **(1)**

$NH_{3(aq)} + HCl_{(aq)} \longrightarrow NH_4Cl_{(aq)}$ **(1)**

n(NH_3) = n(HCl) = 3.785 x 10^{-3} mol **(1)**

n(N in protein) = n(NH_3) = 3.785 x 10^{-3} mol **(1)**

m(N in protein) = n x M = (3.785 x 10^{-3}) x 14.01 = 0.0530 g **(1)**

%(N) = [m(N in protein) / m(protein)] x 100 = [0.0530 / 0.895] x 100 = 5.92%
(1)

Question 12

Contrary to expectations, the size of an atom as measured by its atomic radius does not simply increase as the number of subatomic particles in the atom increases. Explain this statement using diagrams

Happens across period
Increase in nuclear charge due to increase in number of protons
No increase in screening effect as still the same energy level
Increase in core charge (number of protons – inner electrons)
Increased repulsion but e- held closer due to increasingly positive nucleus
Radius increases down a group due to increased number of energy levels, screening effect etc… [6M]

Using three examples of your choice, explain the following statement. Use relevant bonding diagrams in your answer.
"There is a continuum from pure covalent bonding, through polar covalent bonding, to ionic bonding"

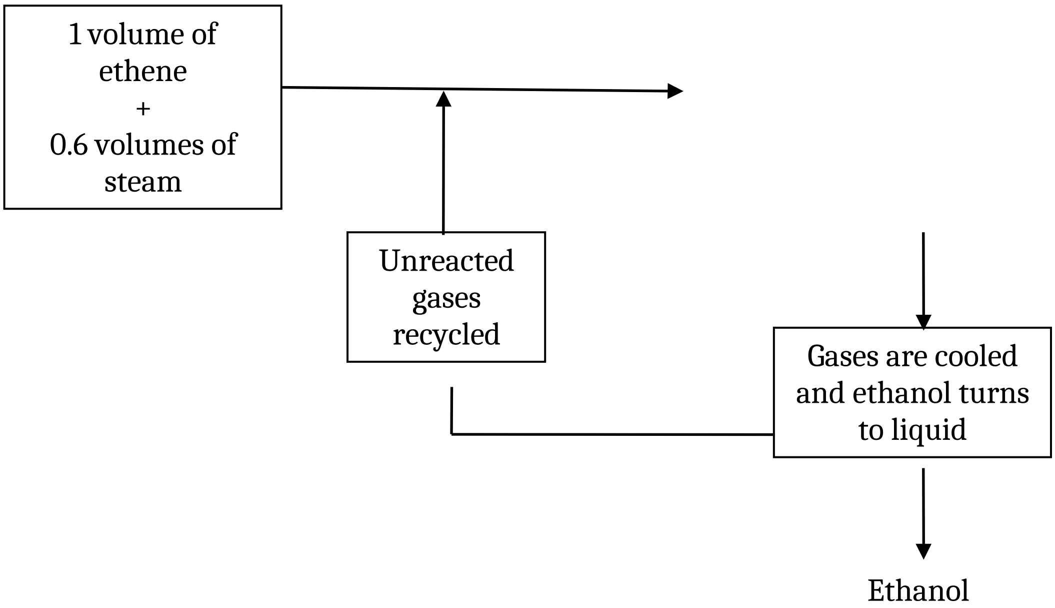
Bonding is the force of attraction between atoms in a molecule
Electronegativity (EN) is the measure of the power of an atom for the shared pair of electrons in a covalent bond
The greater the EN value the greater the ability to take the electrons
Pure covalent – equal EN value both have equal share of electrons
Polar covalent – one atom has greater attraction for shared electrons as has higher EN, e- spend more time around this atom creating a positive dipole (is asymmetrical molecule)
Ionic – large EN difference greater that 1.7 one atom takes the shared pair of electrons and forms a negative ion other atom is the positive ion. [6M]

Question 13
The industrial process of ethanol is an increasingly important one, the equation for this reaction is:

$$C_2H_{4(g)} + H_2O_{(g)} \rightleftharpoons C_2H_5OH_{(g)} \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

A flow chart for the reaction looks like this:

300°C
65 atm
Phosphoric (V) acid coated in SiO_2 catalyst



a) State and explain the ideal conditions for increased rate of the formation of ethanol. [2M]
High temp, high pressure

b) State and explain the ideal conditions for increased yield of ethanol. [2M]
Low temperature, high pressure

c) Explain the compromises made, and the reasons for these, in the actual conditions used in the industrial production of ethanol. [2M]
Intermediate temp and pressure due to safety and cost

d) Catalysts are used in this process. State and explain their function in industrial processes with the aid of an energy profile diagram. [3M]
Provide alternative route with a lower activation energy for the reaction therefore increasing the particles with sufficient activation energy

e) Theoretically what mass of ethanol is produced from 10 000L of ethene at the conditions listed above? [6M]
PV= nRT n x M = 636,545.567g = 637 000 g C_2H_5OH

f) Theoretically if 350L of ethanol were produced what is the % efficiency of the process [2M] 350/10000 x 100 = 3.50%

g) Using the collision theory explain why it is important to remove the ethanol from the system and add more reactants as well as recycling the unreacted gases[3M]
The concentrations of the solutions decreases during the reaction. [1]
According to the collision theory, reactions occur due to successful collisions between reactant particles. [1M]
As the concentration of particles is initially higher, the frequency of collisions will be greater after the number of ethanol molecules increase the number of successful collisions is lower(1M)

Question 14

(a) $n(CeO_2) = m/M = 2.312/172.1147 = 1.343 \times 10^{-2}$ moles **(1)**
$n(Ce(IV)) = n(CeO_2) = 1.343 \times 10^{-2}$ moles **(1)**

This Ce(IV) comes from the Ce(III) and Ce(IV) in the original mass of sample before oxidation of Ce(III).

Hence, n(Ce(III) + Ce(IV)) in 2.167 g sample = 1.343×10^{-2} moles

m(Ce(III) + Ce(IV)) in 2.167 g sample = n x M = (1.343×10^{-2}) x 140.1159
= 1.882 g **(1)**

In 1.528 g sample, n(NO_3^-) = m/M = 0.5230/62.0049 = 8.435×10^{-3} mol **(1)**
3 mol of NO_3^- are found in 1 mole of $Ce(NO_3)_3$
Therfore n($Ce(NO_3)_3$) = n(NO_3^-)/3 = (8.435×10^{-3})/ 3 = 2.812×10^{-3} **(1)**
n(Ce(III)) = n($Ce(NO_3)_3$) = 2.812×10^{-3} **(1)**
m(Ce(III)) = n x M = (2.812×10^{-3}) x 140.1159 = 0.3940 g **(1)**
%(Ce(III)) = [m(Ce(III))/m(sample)] x 100 = [0.3940/1.528] x 100 = **25.8% (1)**

In 2.167 g of sample, m(Ce(III)) = (25.8/100) x 2.167 = 0.5587 g **(1)**
In 2.167 g of sample, m(Ce(III) + Ce(IV)) = 1.882 g

Therefore m(Ce(IV)) in 2.167 g sample = 1.882 – 0.5587 = 1.323 g **(1)**

%(Ce(IV)) = [m(Ce(IV))/m(sample)] x 100 = [1.323/2.167] x 100 = **61.1 % (1)**

(b) n(I_2) = 2 x n(CeO_2) = (2 x 1.343×10^{-2}) = 2.687×10^{-2} moles **(1)**

p(I_2) = (nRT)/V = [(2.687×10^{-2}) x 8.31451 x 298] / 0.2554 = **261 kPa (1)**

Question 15

n(CO_2) = PV/RT = (154.2 x 3.72)/(8.3145 x 300) = 0.2300 mol **(1)**
n(Na) = m/M = 4.52 / 22.9897 = 0.1970 mol **(1)**

How many moles of Na is needed to consume all the CO_2?
n(Na) = 4 x [n(CO_2)/3] = 4 x [0.2300 / 3] = 0.3066. We only have 0.2300. Hence, sodium is the limiting reagent **(1)**.

$n(Na_2CO_3)$ = 0.5 x n(Na) =0.5 x 0.1970 = 0.0983 mol **(1/2)**
$m(Na_2CO_3)$ = n x M = 0.0983 x 105.988 = **10.4 g (1/2)**
$n(CO_2)_{used}$ =(3/4) x n(Na) = (3/4) x 0.3066 = 0.147 **(1)**
$n(CO_2)_{remaining}$ = $n(CO_2)_{start}$ - $n(CO_2)_{used}$ = 0.2300 - 0.147 = **0.0825 mol (1)**

Question 16

%(Mn) = [M(Mn)/M(MnO_2)] x 100 = (54.9380/86.9368) x 100 = 63.19 **(1)**

n(Mn) = m/M = (2.50 x 10^6)/54.9380 = 4.55 x 10^4 **(1)**

$n(MnO_2)$ = n(Mn) = 4.55 x 10^4 **(1)**

$m(MnO_2)$ = n x M = (4.55 x 10^4) x 86.9368 = 3.96 x 10^6 g **(1)**

%(MnO_2) = [m(MnO_2)/m(ore)] x 100

47.2 = [(3.96 x 10^6)/m(ore)] x 100 **(1)**

m(ore) = 8.38 x 10^6 g = **8.38 tonnes (1)**

Question 17

Rate correct [1M]
Yield correct [1M]
Eq correct [1M]
Equation {1M]
Layout [1M]