Methodist Ladies' College Semester 1, 2014

SOLUTIONS

CHEMISTRY

STAGE 2

Section One: Multiple-choice **25% (40 Marks)**

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

Section Two: Short answer **45% (70 Marks)**

Question 21 **(9 marks)**

(a) Complete the table below by adding the name of an **element** from **atomic number 1 to 20** of the Periodic Table for each of the types of bonding and structure described.

(4 marks)

Bonding and structure at room temperature and pressure	**Name of Element**
metallic solid	calcium
monatomic gas	**helium, neon or argon**
covalent network solid	**carbon or silicon**
covalent molecular gas	**hydrogen, nitrogen, oxygen, fluorine or chlorine**
covalent molecular solid	**phosphorus or sulfur**

(b) Why do metallic solids such as calcium conduct electricity? (2 marks)

metallic solids are 3-D lattices of cations held in a fixed position surrounded by a sea of delocalised valence electrons. These electrons are free to move and transfer electric charge.

(c) Covalent bonding is common to both network and molecular solids. Why do covalent network solids have extremely high melting points but covalent molecular solids have low melting points?

(3 marks)

To melt a covalent network substance the strong covalent bonds between atoms extending throughout the lattice must be broken. This requires a large amount of energy resulting in an extremely high melting point. To melt a molecular solid only weak forces between molecules are overcome and this requires only a small amount of energy which explains the low melting point.

Question 22 **(8 marks)**

Complete the table below by naming or giving the formula for the following substances.

Name	Formula
aluminium chloride	**$AlCl_3$**
ethanoic acid	**CH_3COOH**
diphosphorus pentoxide	P_2O_5
tin(IV) sulfide	**SnS_2**
calcium oxalate	CaC_2O_4
potassium dichromate	**$K_2Cr_2O_7$**
iron(III) nitrate	$Fe(NO_3)_3$
sodium hydrogenphosphate	Na_2HPO_4

Question 23 **(9 marks)**

Some physical properties of ethanol are shown in the table below.

colour	melting point	boiling point at atmospheric pressure	vapour pressure at 20℃	Mass of 1.00 mL
colourless	-114℃	78℃	5.85 kPa	0.785 g

(a) Complete the following sentences by inserting the words, **less than**, **greater than** or **equal to**.

(3 marks)

(i) At 50℃ the vapour pressure of ethanol is **greater than** 5.85 kPa.

(ii) The boiling point of a solution of copper(II) chloride dissolved in ethanol is **greater than** 78℃.

(iii) The melting point of a solution of copper(II) chloride dissolved in ethanol is **less than** - 114℃.

(b) 25.0 mL of ethanol, C_2H_5OH, is dissolved in water producing 150.0 mL of solution.

(i) What mass of ethanol is dissolved in the water? (1 mark)

m(ethanol) = 25.0 x 0.785 = 19.6 g

(ii) Determine the concentration of the solution in mol L^{-1}. (2 marks)

n(ethanol) = $\frac{m}{M}$ = $\frac{19.6}{46.068}$ = 0.4255 c = $\frac{n}{v}$ = $\frac{0.4255}{0.150}$ = 2.24 mol L^{-1}

DO NOT WRITE IN THIS AREA

(c) A cocktail was prepared by mixing 50.0 g of 40.0% ethanol by mass gin and 60.0 g of 35.5% ethanol by mass dry martini.

(3 marks)

What amount in moles of ethanol did the drinker consume?

m(ethanol) from gin = 40/100 x 50.0 = 20.0 g

m(ethanol) from dry martini = 35.5/100 x 60.0 = 21.3 g

total mass of ethanol = 41.3 g

n(ethanol) = $\frac{m}{M}$ = $\frac{41.3}{46.068}$ = 0.897 mol

Question 24 **(4 marks)**

Explain using your knowledge of kinetic theory and the behavior of gases why:

(a) Carbon dioxide gas will bubble out of soft drinks when the can is opened. (2 marks)

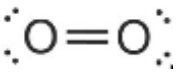
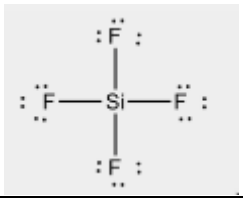
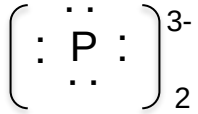
Opening the can reduces the pressure of CO_2 within the can. The solubility of gases decreases with decreasing pressure and so CO_2 bubbles out of solution.

(b) People perspire on a hot day in order to cool down. (2 marks)

Evaporation has a cooling effect (is endothermic) as the high kinetic energy particles escape reducing the average K.E and therefore temperature of the remaining liquid. (evaporation is a bond breaking process and so energy moves from the surroundings into the system, the surroundings cool)

Question 25 **(6 marks)**

For the species listed in the table below, draw electron dot diagrams. All valence shell electron pairs should be represented as : or —

Name or formula	electron dot diagram
O_2	
SiF_4	
magnesium phosphide	$[Mg]^{2+}{}_3$ 

Question 26 **(4 marks)**

Consider two 1 litre gas jars at 25℃ and atmospheric pressure, one containing methane gas, CH_4, and the other, carbon monoxide gas, CO.

Complete the table below by circling the correct answer when comparing methane gas with carbon monoxide gas.

characteristic	Compared with carbon monoxide (CO) methane (CH_4) has :
a. average Kinetic energy	**same** higher lower
b. average velocity	same **higher** lower
c. number of molecules	**same** higher lower
d. amount in moles	**same** higher lower

Question 27 **(4 marks)**

Chromium sulfide reacts with hydrochloric acid to produce hydrogen sulfide gas (H_2S) and chromium chloride solution.

(a) Wrire a balanced equation for the reaction described and give full observations

(3 marks)

Equation **$Cr_2S_3(s) + 6H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3H_2S(g)$**

or ***$6HCl(aq)$*** ***$2CrCl_3(aq)$***

Observations **deep green solid dissolves in colourless solution, fizzing, colourless gas produced as solution turns deep green.**

(b) An ore containing a mixture of chromium metal and chromium sulfide was treated with excess hydrochloric acid. As well as hydrogen sulfide gas a second gas was produced. Identify that gas.

(1 mark)

Hydrogen (H_2)

Question 28 **(2 marks)**

A pressure cooker is a cooking device that has a deep pan with a lid to form an airtight seal when closed. Water is added to a pressure cooker and the water is able to reach a temperature of approximately 120 °C.

Water in a normal saucepan will boil at 100 °C. Explain how the water in a pressure cooker is able to boil at 120 °C.

(2 marks)

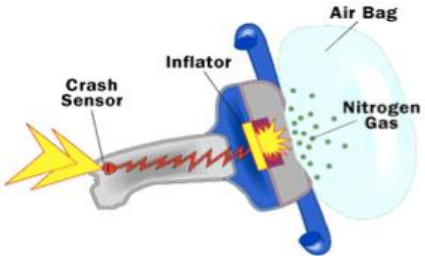
DO NOT WRITE IN THIS AREA

The pressure within the pressure cooker is higher than atmospheric pressure and so more energy is needed to raise the vapour pressure to the internal atmospheric pressure for boiling to occur. The temperature of the boiling water is therefore higher.

Question 29 **(7 marks)**

The air bags in cars inflate when activated by a crash sensor. Nitrogen gas is produced to inflate the bags in a three-step process. In the first step, sodium azide (NaN_3) decomposes according to the equation below.

$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$



(a) 135 g of sodium azide is stored separately in the inflator chamber. The crash sensor causes the sodium azide to decompose and nitrogen gas is blasted into the air bag.

Calculate the volume of nitrogen produced from 135 g of sodium azide at STP

(3 marks)

mol(NaN_3) → mol(N_2) → vol(N_2) at STP

n(NaN_3) = $\frac{m}{M}$ = $\frac{135}{65.02}$ = 2.076

from equation, n(N_2) = $\frac{3}{2}$ n(NaN_3) = $\frac{3}{2}$ x 2.076 = 3.114

v(N_2) at STP = n22.71 = 3.114 x 22.71 = 70.7 L

(b) In another chamber potassium nitrate is mixed with the sodium metal to produce potassium oxide, sodium oxide and nitrogen gas. Write a balanced equation for this reaction.

(2 marks)

$10Na(s) + 2KNO_3(s) \rightarrow K_2O(s) + 5Na_2O(s) + N_2(g)$

(c) The nitrogen inflating the bag is not at standard temperature and pressure but usually around 40℃. Would the actual volume of nitrogen gas inflating the bag be greater or less than the answer to (a) above? Explain.

(2 marks)

Greater than. Since in a flexible container as the temperature increases the volume Increases. This occurs because of the increase in average K.E of the molecules, they collide more often and with greater force with the inner walls of the bag, pushing out to maintain pressure (internal = external)

Question 30 **(3 marks)**

Name all the particles that carry the charge when electricity flows in the following substances:

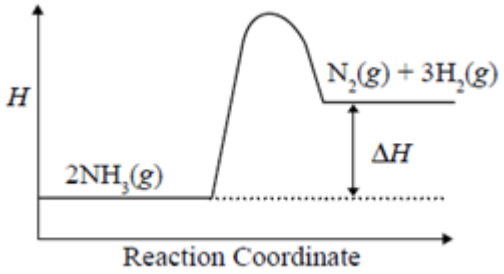
(a) molten silver **delocalised electrons and mobile cations**

(b) an aqueous solution of copper sulfate **$Cu^{2+}(aq)$ and $SO_4^{2-}(aq)$ ions**

(c) solid copper **delocalised electrons**

Question 31 **(8 marks)**

(a) State whether the following processes are endothermic or exothermic. (5 marks)

Process	Endothermic or exothermic
$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s) + 993$ kJ	**exothermic**
Combustion of petrol	**exothermic**
	**endothermic**
When ammonium nitrate is added to water in a beaker, the beaker feels cold to the touch.	**endothermic**
$2N(g) \rightarrow N_2(g)$	**exothermic**

(b) The equation for the reaction between calcium oxide, CaO, and water can be represented as:

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) \qquad \Delta H = -82.0 \text{ kJ mol}^{-1}$$

Calculate the mass of calcium oxide required to release 287 kJ of energy.

(3 marks)

from equation 1 mol or 56.08 g of CaO releases 82 kJ of energy

for 287 kJ energy need $\frac{287}{82}$ x 56.08 = 196 g

Question 32 **(6 marks)**

Give the chemical formula or name of a species that matches the description in the table below:-

Description	Example (formula or name)
An element that exists as a silver liquid at room temperature	**mercury Hg**
An ionic compound that consists of only non-metal atoms	**e.g. ammonium chloride NH_4Cl**
The most reactive element in group 2	**radium Ra**
A halogen which is a solid at room temperature	**iodine I_2**
A yellow solid with a high melting pt that is malleable	**gold Au**
A substance that undergoes ionisation when added to water and produces a strong electrolyte	**hydrogen chloride HCl**

Section Three: Extended answer **30% (50 Marks)**
Question 33 **(24 marks)**

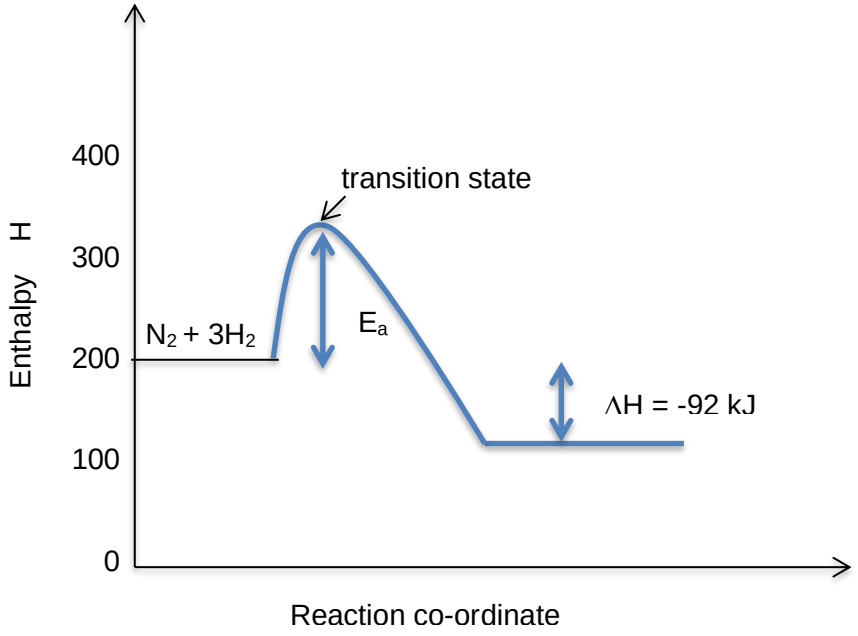
The Haber process is the industrial manufacture of ammonia from nitrogen and hydrogen.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) \quad \Delta H = -92kJ$$

The reaction does not occur readily. It requires a high temperature and pressure as well as a catalyst. The activation energy is 120 kJ.

(a) Complete the energy profile diagram for this reaction. Label:
- both axis
- activation energy
- enthalpy change
- transition state.

(5 marks)



(b) Rewrite the equation for the reaction including the energy term as part of the equation.

(1 mark)

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 92\ kJ$

(c) If 6.00×10^3 kL of nitrogen reacts completely. What maximum volume of ammonia, measured at the same temperature and pressure could be produced.

(1 mark)

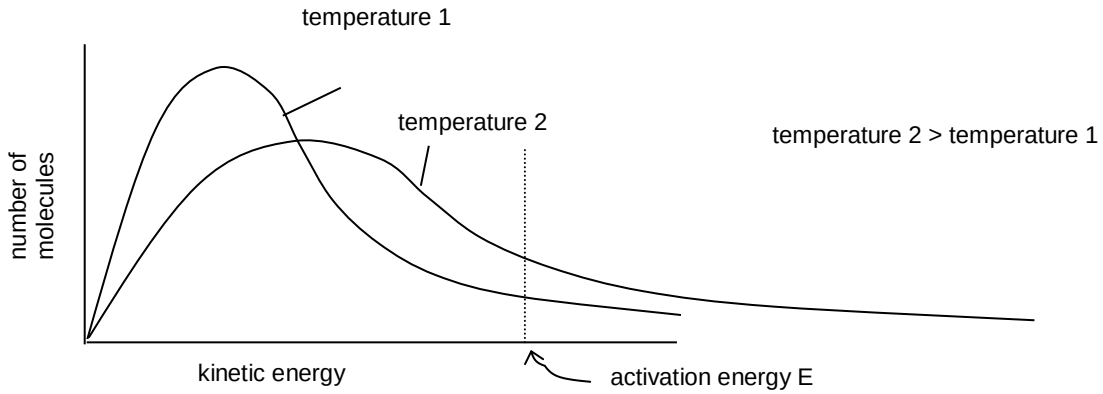
$v(NH_3) = 2v(N_2) = 2 \times 6.00 \times 10^3 = 1.20 \times 10^4$ L

(d) Using relevant theories, explain fully how the conditions used for this industrial process, high temperature, catalyst and high pressure, result in a very good rate of reaction. Diagrams/graphs may assist your explanation.

(9 marks)

High temperature

High temperature increases the average K.E. of the molecules, this means that they move faster and collide more frequently but more importantly it increases the proportion of molecules with sufficient energy, more than the minimum E_a, to collide successfully therefore increasing the frequency of successful collisions.

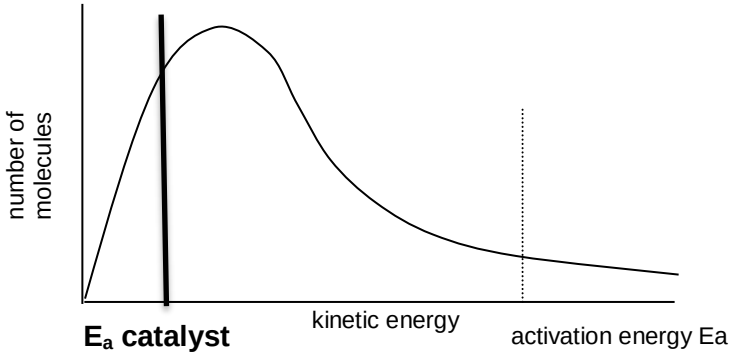


High pressure

Increasing the pressure of gases causes an increase in concentration as the molecules are pushed closer together. This increases the frequency of collisions and therefore more successful collisions occur in a given time interval increasing the rate of reaction

Catalyst

Catalysts provide an alternative pathway for the reaction with a lower activation energy. This means that a larger proportion of molecules have more than the minimum activation energy to collide successfully resulting in a greater frequency of successful collisions and faster rate.



E_a catalyst

(e) Ammonia is used to manufacture the fertilizer ammonium nitrate, NH_4NO_3. Calculate the percentage by mass of nitrogen in ammonium nitrate.

(2 marks)

% N = $\frac{2 \times 14.01}{M(NH4NO3)} = \frac{28.02}{80.052}$ x 100 = 35.0%

(f) Plants also use phosphorous to promote growth and health. 50.0 g of ammonium phosphate, $(NH_4)_3PO_4$, was mixed with 75.0 g of ammonium nitrate. This mixture was dissolved in enough water to make 875 mL of solution.

(i) This solution can be described as a homogenous mixture. Explain the term homogenous.

(1 mark)

uniform in properties and composition throughout

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(ii) Calculate the concentration of ammonium ions in the solution.

(5 marks)

$n((NH_4)_3PO_4) = \frac{m}{M} = \frac{50.0}{149.096} = 0.3353$ mol

$n(NH_4^+) = 3\ n((NH_4)_3PO_4) = 3 \times 0.3353 = 1.006$ mol

$n(NH_4NO_3) = \frac{m}{M} = \frac{75.0}{80.052} = 0.9369$ mol $= n(NH_4^+)$

total $n(NH_4^+) = 1.006 + 0.9369 = 1.943$ mol

$c(NH_4^+) = \frac{total\ n}{total\ v} = \frac{1.943}{0.875} = 2.22$ mol L^{-1}

Question 34 **(12 marks)**

The labels have fallen from 4 bottles known to contain the following white solids:

sodium sulfate, sodium chloride, sodium carbonate and calcium phosphate.

You have available:

- Distilled water
- Barium hydroxide solution
- Nitric acid
- Sodium hydroxide solution

Describe how you could carry out a series of simple tests that would allow you to identify each of the white solids and correctly label the bottles. You may not have to use all the chemicals provided. Describe the distinguishing observations for each test and give ionic equations for any chemical reactions occurring. **3 Tests** should be sufficient.

Test	Distinguishing Observations	Substance/s identified	Relevant equation (if necessary)
Solubility of solid in distilled water	**3 dissolve and 1 is insoluble**	**$Ca_3(PO_4)_2$**	
Add nitric acid to each remaining solids (or solution of solids)	**Only 1 fizzes producing colourless gas**	**Na_2CO_3**	**$Na_2CO_3(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + CO_2(g) + H_2O(l)$**
Add barium hydroxide solution to a solution of each of the remaining solids	**1 gives white ppt** **1 gives no change**	**Na_2SO_4** **NaCl**	**$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$**

Question 35 **(14 marks)**

The data in the table below describes the solubility of ammonium nitrate, NH_4NO_3, and potassium chlorate, $KClO_3$ in water.

Salts	Solubility at different temperatures (g of salt in 100 g of water)					
	10℃	25℃	40℃	50℃	55℃	60℃
NH_4NO_3	15	24	35	47	59	75
$KClO_3$	3	5	9	18	25	36

(a) Plot the data on the graph paper opposite (your graph should take up most of the space available). **Page 27 has an additional piece of graph paper if required.**

Label the axis fully and clearly indicate which salt is represented by each curve.

(5 marks)

(b) At 30℃ what would be the concentration of a saturated solution of ammonium nitrate in g L^{-1}? (Assume that 1.00 mL of water has a mass of 1.00g)

(2 marks)

from graph 31 g NH_4NO_3 dissolves in 100 ml or 100 g of water at 30℃

therefore 10 x 31 = 310 g will dissolve in 1000 ml

c = 3.10 x 10^2 g L^{-1}

(c) 70 g of potassium chlorate was dissolved in 200 g of water at 100℃. This solution was cooled to 15℃.

What mass of potassium chlorate would recrystallise from the solution.

(2 marks)

from graph at 15℃ 3.5 g of KClO3 dissolves in 100 g of water

therefore 7.0 g will dissolve in 200 g of water

mass that will recrystallize = 70 – 7 = 163 g

(d) Calculate the mass of solute in 47 g of a saturated solution of ammonium nitrate at 40℃.

(3 marks)

from graph or table at 40℃ 35 g NH_4NO_3 dissolves in 100 g of water.

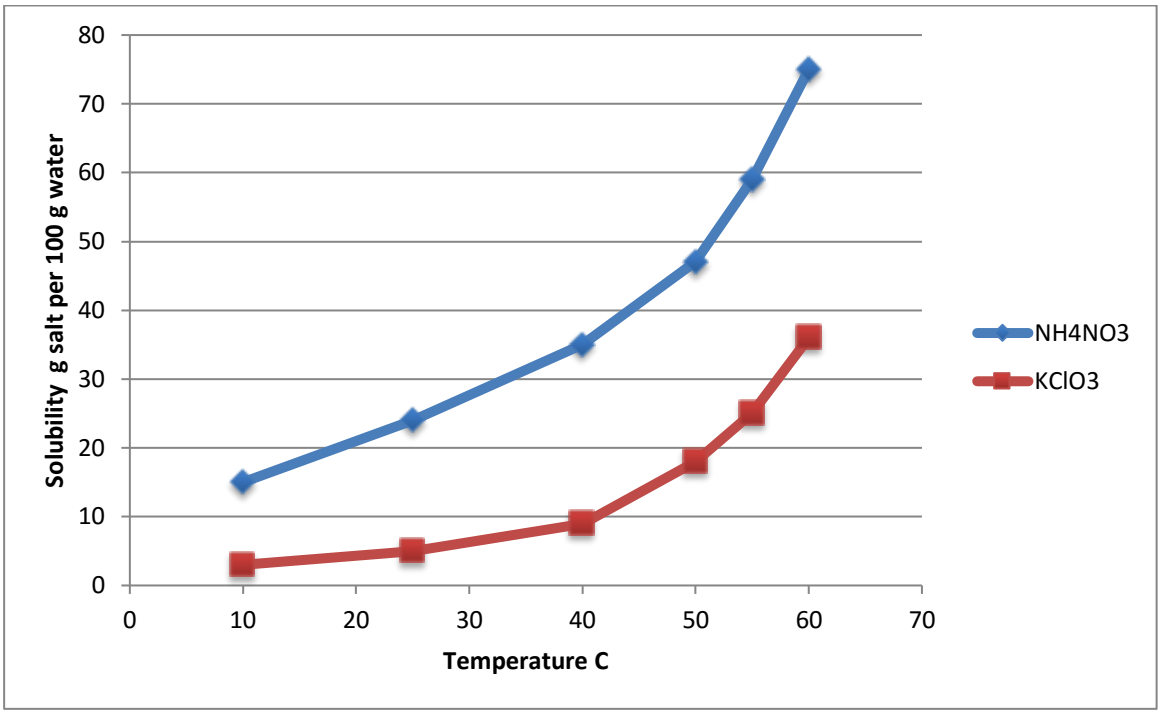
% m/m = $\frac{m(solute)}{m(solution)}$ x 100 = $\frac{35}{135}$ x 100 = 25.93%

m(solute) in 47 g = $\frac{25.93}{100}$ x 47 = 12.2 g

(e) Both salts in this question are described as strong electrolytes. Silver chloride is also described as a strong electrolyte yet even at 100℃ its solubility is only slightly greater than 1.2 g AgCl per 100g of water. Explain. (2 marks)

strong electrolytes exist entirely as ions in solution, although AgCl is described as insoluble, the small amount that does dissolve exists entirely as ions.

Solubility curves



END OF QUESTIONS