UNIT 3ACHE

PENRHOS COLLEGE

STRIVE FOR THE HIGHEST

RATES & EQUILIBRIUM

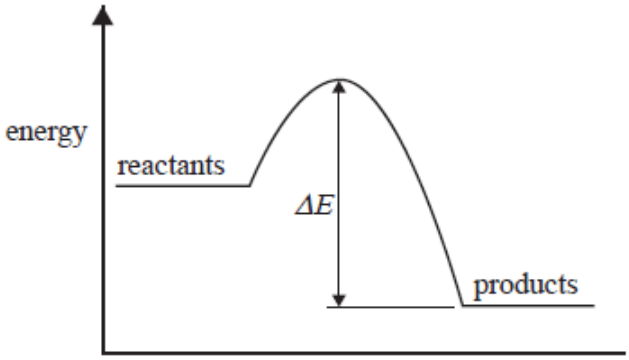
NAME:_____ **TIME ALLOWED: 60 MINUTES**

Section One: Multiple Choice Questions. (10 marks)

1. The addition of a catalyst to a chemical reaction

   A. lowers the activation energy required for the reaction to occur.
   B. lowers the chemical energy of the products.
   C. lowers the chemical energy of the reactants.
   D. lowers the value of the enthalpy change for the reaction.

2. The change in energy during a reaction is represented in the following energy profile diagram.



   The change in energy labelled *ΔE* above is

   A. the energy absorbed when bonds in the reactants break.
   B. the activation energy of the forward reaction.
   C. the activation energy for the reverse reaction.
   D. the heat of reaction.

3. If, for the reaction

   $C_2H_5OH_{(g)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$; $\Delta H = -1364$ kJ mol^{-1}

   then the ΔH value for $4CO_{2(g)} + 6H_2O_{(l)} \rightarrow 2C_2H_5OH_{(g)} + 6O_{2(g)}$ would be

   A. +2728 kJ
   B. +1364 kJ
   C. +682 kJ
   D. –1364 kJ

4. Consider the following equilibrium

$$2ClF_{3(g)} \rightleftharpoons 3F_{2(g)} + Cl_{2(g)}; \qquad \Delta H = -\text{ve}$$

For a particular equilibrium mixture, the temperature is **lowered** and the amount of ClF_3 changes by 0.010 mol.

The changes occurring would be

	ClF_3	F_2	Cl_2
A.	Increase by 0.010 mol	Decrease by 0.015 mol	Decrease by 0.0050 mol
B.	Increase by 0.010 mol	Decrease by 0.0067 mol	Decrease by 0.020 mol
C.	Decrease by 0.010 mol	Increase by 0.015 mol	Increase by 0.0050 mol
D.	Decrease by 0.010 mol	Increase by 0.067 mol	Increase by 0.020 mol

5. The concentrations of reactants and products were studied for the following reaction.

$$H_{2(g)} + F_{2(g)} \rightleftharpoons 2HF_{(g)} \; ; \; K = 313 \text{ at } 25°C$$

In an experiment, the initial concentrations of the gases were
$[H_2] = 0.0200$ M, $[F_2] = 0.0100$ M and $[HF] = 0.400$ M

When the reaction reaches equilibrium at 25°C, the concentration of HF will be

A. 0.400 M

B. 0.420 M

C. between 0.400 M and 0.420 M

D. less than 0.400 M

6. The anaesthetic, nitrous oxide, N_2O, decomposes to form an equilibrium mixture of N_2O, N_2 and O_2 according to the following equation.

$$2N_2O_{(g)} \rightleftharpoons 2N_{2(g)} + O_{2(g)}$$

At 25°C, $K = 7.3 \times 10^{37}$ M and at 40°C, $K = 2.7 \times 10^{36}$ M

What valid conclusion can be made from this?

A. The equilibrium concentrations of N_2 and O_2 are equal at 25°C.

B. The equilibrium concentration of N_2O is higher at 25°C than at 40°C.

C. N_2O is less stable at the higher temperature.

D. The forward reaction is exothermic.

7. The OCl^- ion acts as a base in water according to the equation

$$OCl^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + OH^-_{(aq)}$$

When two drops of 5.0 M NaOH are added to an equilibrium mixture of OCl^- in water at constant
temperature

A. the pH of the solution decreases.

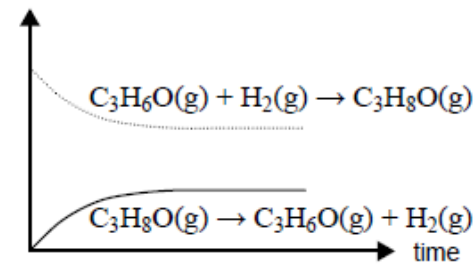
B. the concentration of OH^- increases.

C. the concentration of HOCl increases.

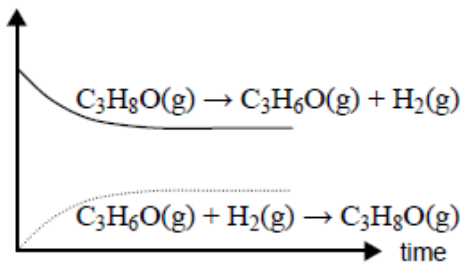
D. the ratio $[OCl^-]/ [HOCl] [OH^-]$ increases.

8. When 2-propanol reacts to form an equilibrium mixture with propanone and hydrogen, which one of the following best represents how the **rates** of the forward and back reactions change over time?

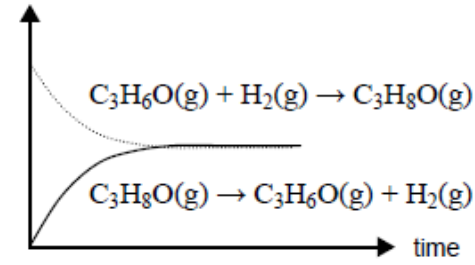
A.



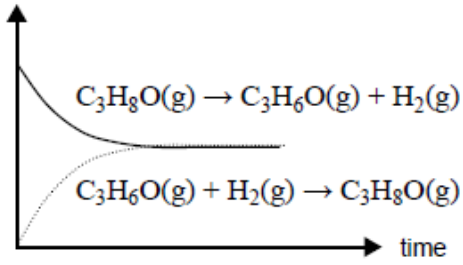
B.



C.



D.



9. It is known that carbon monoxide reacts exothermically with hydrogen gas to form methanol at

400^0C, in the presence of a catalyst.

$$CO_{(g)} + 2H_{2\,(g)} \rightleftharpoons CH_3OH_{(g)} + \text{heat}$$

A mixture of carbon monoxide, hydrogen gas and methanol placed under conditions described above achieves equilibrium in a closed container. If the reaction temperature is changed to 450^0C, which of the following statements is correct?

A. The reaction rates of both the forward and reverse reactions remain constant.

B. Total pressure within the container increases.

C. Rate of formation of hydrogen decreases while the rate of decomposition of methanol increases.

D. The total number of molecules in the container decreases.

10. 1 mole of nitrogen gas and 3 moles of hydrogen gas were added to a rigid 1 L container at 298 K and left to react. At equilibrium it was found that the concentrations of nitrogen, hydrogen and ammonia were 0.116 mol L^{-1}, 0.348 mol L^{-1} and 1.768 mol L^{-1} and the pressure inside the container was 5.5 x 10^3 kPa.

1 mole of hydrogen chloride gas was subsequently added to the container and the system was left to re-establish equilibrium (hydrogen chloride gas reacts with ammonia gas to produce solid ammonium chloride).

What are the concentrations (or range of concentrations) of nitrogen, hydrogen, ammonia and hydrogen chloride once equilibrium has been reached for the second time?

	Final concentration (mol L^{-1})			
	$[N_2]$	$[H_2]$	$[NH_3]$	[HCl]
A.	0.116	0.348	0.768	0
B.	$0<[N_2]<0.116$	$0<[H_2]<0.348$	$0<[NH_3]<1.768$	0
C.	0.116	0.348	1.768	1
D.	$0<[N_2]<0.116$	$0<[H_2]<0.348$	$0<[NH_3]<1.768$	1

End of Section One

Section Two: Short Answer Questions (15 marks)

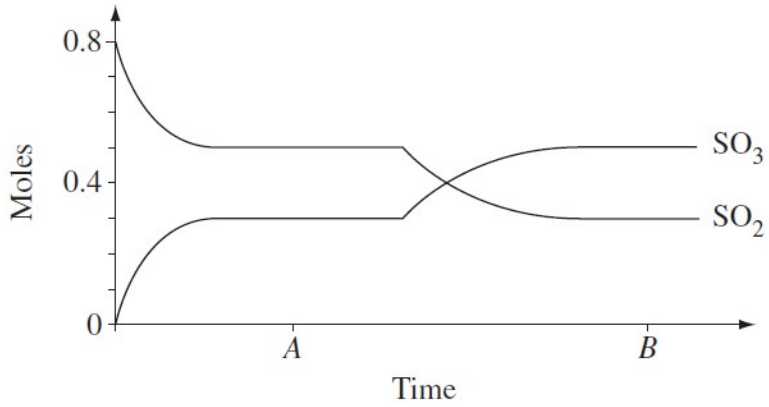
11. One of the steps involved in the industrial preparation of sulfuric acid is the oxidation of sulfur dioxide to sulfur trioxide .

A. Write an equation to represent this reaction

_____

1 mark

At room temperature 0.80 moles of SO_2 and 0.40 moles of O_2 were introduced into a sealed 10 L vessel and allowed to come to equilibrium.



B. Write the equilibrium constant expression for the reaction

_____

1 mark

C. Calculate the value for the equilibrium constant at time *A*.

_____

_____

_____

_____

_____

_____

_____

2 marks

D. Explain why a new equilibrium position was established at time *B*.

_____

_____

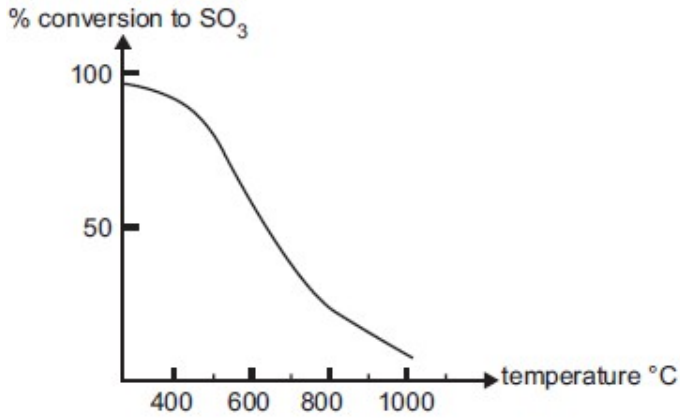
1 mark

E. Give the name **or** formula for the catalyst that is most widely used for this reaction.

_____

1 mark

The graph below shows the percentage conversion of sulfur dioxide to sulfur trioxide at equilibrium at a pressure of101.3 kPa and various temperatures.



F. There is almost complete conversion of sulfur dioxide to sulfur trioxide at 300°C. Explain why this reaction is performed at a higher temperature of approximately 450°C in industry.

_____

_____

1 mark

G. Explain why high pressures would increase the equilibrium yield of sulfur trioxide in this reaction.

_____

_____

_____

1 mark

H. Explain why atmospheric pressure is **usually** used in industry, even though high pressures increase the equilibrium yield of sulfur trioxide in this reaction.

_____

_____

1 mark

A chemical reaction that involves sulfuric acid occurs in each of the following situations. Write a balanced chemical equation for each reaction.

I. Dilute sulfuric acid is added to sodium carbonate solution.

_____ 1 mark

J. Sulfur trioxide gas is bubbled through concentrated sulfuric acid.

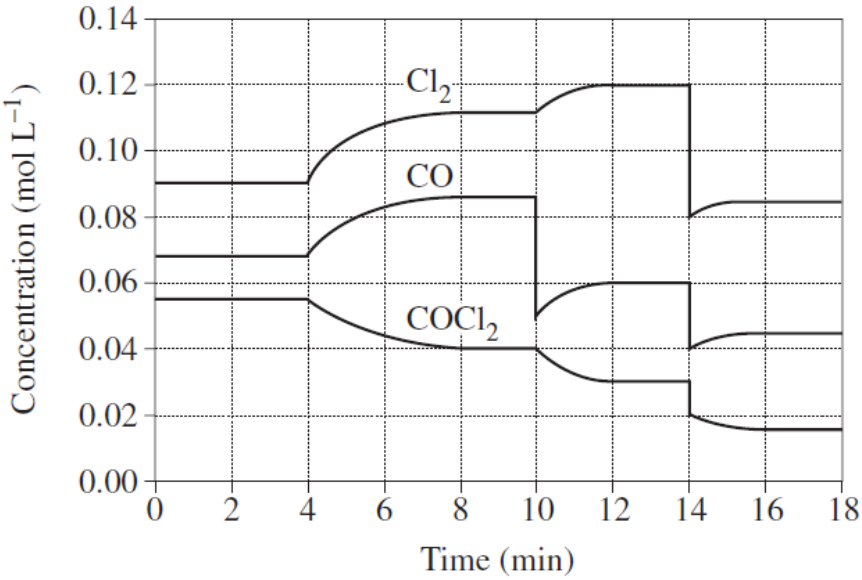
_____ 1 mark

K. A piece of zinc metal is added to 6 M sulfuric acid. Zinc ions are formed as well as an oxide of sulfur in which sulfur exhibits an oxidation state of +4.

_____ 1mark

12. The graph shows the variation in concentration of reactant and products as a function of time for the following system.

$$COCl_{2(g)} \rightleftharpoons Cl_{2(g)} + CO_{(g)} ; \qquad \Delta H = +108 \text{ kJ}$$



Identify each of the changes in conditions that have shaped the curves during the time the system was observed.

4 minute mark: _____

_____

_____

10 minute mark: _____

_____

_____

14 minute mark: _____

_____

_____

3 marks

Section Two: Extended Answer Questions (15 marks)

13. In the reaction between lead(II) nitrate and potassium iodide, lead(II) iodide is formed.

10 marks

A. Write a balanced equation using formula units for this reaction.

_____

1 mark

B. What might you expect to observe in this reaction?

_____

1 mark

2.00 g of lead nitrate is added to 3.00 g of potassium iodide,

C. Identify the limiting reagent.

_____

_____

_____

_____

_____

_____

_____

_____

3 marks

D. calculate the mass of lead(II) iodide formed

_____

_____

_____

_____

_____

_____

2 marks

E. calculate the mass of excess reactant remaining after the reaction.

3 marks

14. **“Distinguish between rate and extent of a reaction and explain clearly the circumstances under which a rise in temperature may result in an increase in both for one reaction, and an increase in one and a decrease in the other in another reaction “.**

5 marks

END OF TEST

UNIT3ACHE **SOLUTIONS**

RATES AND EQUILIBRIUM 2011: **Answer all questions**

Section One: MULTIPLE CHOICE QUESTIONS (10 marks)

1A	2C	3A	4C	5D	6D	7B	8D	9B	10B

Section Two: Short Answer Questions (15 marks)

11.

A. $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ 1 mark

B. $K_{eq} = \dfrac{[SO_3]^2}{[SO_2]^2\,[O_2]}$ 1 mark

C. At time A

$n(SO_3) = 0.3$ mol; $[SO_3] = 0.3/10 = 0.03$ molL^{-1}

$n(SO_2) = 0.5$ mol; $[SO_3] = 0.5/10 = 0.05$ molL^{-1}

$n(O_2)_{reacting} = ½ \times n(SO_2)_{reacting} = ½ \times (0.8 - 0.5) = ½ \times 0.3$ mol $= 0.15$

$n(O_2)_{at\ equilibrium} = 0.4 - 0.15 = 0.25$; $[O] = 0.25/10 = 0.025$ molL^{-1} 1 mark

$K_{eq} = 0.3^2 \div (0.05^2 \times 0.025) = 14.4$ 1 mark

D. $O_{2(g)}$ was introduced into the system 1 mark

(Alternatively: the reaction is exothermic, therefore decreasing the temperature could account for the change because it favours the exothermic process)

E. V_2O_5; vanadium(V) oxide 1 mark

F. increase the rate of reaction (even though it reduces yield i.e. a compromise between rate and yield) 1 mark

G. Increasing the pressure shifts the position of equilibrium towards the product so as to partially counteract the imposed stress i.e. pushes the position of equilibrium in a direction so as to reduce pressure (3 moles → 2 moles)

1 mark

H. K_{eq} is large, therefore yield is high without increasing the pressure. 1 mark

I. $H_2SO_{4(aq)} + Na_2CO_{3(aq)} = Na_2SO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$ 1 mark

J. $SO_{3(g)} + H_2SO_{4(l)} = H_2S_2O_{7(l)}$ 1 mark

K. $2H_2SO_{4(aq)} + Zn_{(s)} = ZnSO_{4(aq)} + SO_{2(g)} + 2H_2O_{(l)}$ 1 mark

12.

4 minute mark: the temperature of the system was increased 1 mark

10 minute mark: CO removed from the system 1 mark

14 minute mark: the pressure of the system was decreased or volume of vessel increased. (This lead to a simultaneous decrease in the concentration of all 3 species)

1 mark

Section Three: Extended Answer Questions (15 marks)

13. **A** $Pb(NO_3)_2\,(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$
OR $Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$ 1 mark

B A yellow ppte/solid forms when the 2 colourless solutions are added together or when the 2 white solids are shaken together 1 mark

C $n(Pb(NO_3)_2) = m/M = 2/331.22 = 6.0383 \times 10^{-3}$ or 0.006038
$n(PbI_2) = (Pb(NO_3)_2) = 6.0383 \times 10^{-3}$ or 0.006038 1 mark
$n(KI) = m/M = 3/166 = 1.8072 \times 10^{-2}$ or 0.01807
$n(PbI_2) = 2 \times n(KI) = 2 \times 1.8072 \times 10^{-2} = 3.611 \times 10^{-2}$ or 0.036144 1 mark
Since 0.006038 < 0.036144
$\underline{Pb(NO_3)_2 \text{ is the limiting reagent}}$ as it produces the least amount of PbI_2 1 mark

D from C. $n(PbI_2)$ produced = $n(Pb(NO_3)_2)$ reacted = 6.038×10^{-3} mol. 1 mark
$m(PbI_2) = n \times M = 6.03828 \times 10^{-3} \times 461 = 2.7836$ g = $\underline{2.78 \text{ g } PbI_2 \text{ produced}}$ 1 mark

E from the equation, $n(KI)_{reacting} = 2 \times n(Pb(NO_3)_2) = 2 \times 6.0383 \times 10^{-3}$
$= 1.2076 \times 10^{-2}$ mol 1 mark
$m(KI)_{reacting} = n \times M = 1.2076 \times 10^{-2} \times 166 = 2.0047$ g 1 mark
$m(KI)_{inxs} = m(KI)_{initial} - m(KI)_{reacting}$
$= 3 - 2.0047 = 0.9953 = \underline{0.995 \text{ g KI}}$ 1 mark

14. Rate of reaction refers to the speed (rate) at which a reaction proceeds i.e. how fast is the reaction.

1 mark

Extent refers to the position of equilibrium i.e. how far towards completion does the reaction go or what is the yield.

1 mark

Temperature is the average E_k of the particles = $\frac{1}{2}mv^2$. Increasing the temperature increases E_k, more particles will have $E \geq E_a$ (Energy of Activation). The velocity of the particles will also increase and there will be more collisions. Regardless of where the position of equilibrium lies, an increase in temperature will give an increased rate of reaction (both forward and reverse rates increasing).

1 mark

The equilibrium constant expression K_{eq} is temperature dependant. An increase in temperature favours the endothermic process. If the reaction as written is endothermic then the extent (yield) to which the reaction goes to completion will increase.

1 mark

On the other hand if the reaction as written is exothermic an increase in temperature favours the endothermic process pushing the position of equilibrium towards the reactants and the extent (yield) to which the reaction goes to completion (towards products) will decrease.

1 mark