UNIT 3 NAME:_____

REACTION RATES & EQUILIBRIUM TEST
Answer all questions

SECTION ONE: Multiple Choice Questions **(10 marks)**

Q1. The best description of the effect of a catalyst on a chemical reaction is that it:

a) lowers the activation energy of both forward and reverse reactions by the same amount.
b) increases the rate of a reaction by providing an alternative pathway which decreases the value of ΔH.
c) increases the rate of the forward reaction more than the rate of the reverse reaction.
d) lowers the activation energy of the forward reaction more than the activation energy of the reverse reaction.

Q2. Doubling the rate of a gas reaction in a closed vessel by raising the temperature from 10° to 20°C is mostly a result of:

a) doubling the average kinetic energy of the reactant molecules
b) doubling the activation energy of the reaction
c) doubling the average speed of the molecules
d) doubling the proportion of molecules that possess the necessary activation energy

Q3. A bottle of the liquid ether sealed with a loose rubber stopper was stored in the fridge. When it was taken out of the fridge and left on the bench at room temperature for a short time the stopper popped out of the bottle. The most likely reason for this is:

a) the kinetic energy of the liquid molecules decreased and the vapour pressure in the bottle became lower than atmospheric pressure.
b) the rate of evaporation of ether was greater than the rate of condensation resulting in an increase in vapour pressure in the bottle.
c) the system re-established equilibrium with a higher value of the equilibrium constant at the new temperature.
d) Evaporation of ether is exothermic and the increase in temperature forced the stopper out of the bottle.

Q4. Which one of the following reactions is endothermic?

a) $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g) + 2046\ kJ$

b) $Al(l) \longrightarrow Al(s) \quad \Delta H = -375\ kJ$

c) $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g) + 2046\ kJ$

d) $2Xe(g) + 3O_2(g) \longrightarrow 2XeO_3(g) \quad \Delta H = 804\ kJ$

Q5. Consider the following system at equilibrium:

$$Cr(OH)_3(s) \longleftrightarrow Cr^{3+}(aq) + 3OH^-(aq)$$

Which of the following changes would increase the concentration of hydroxide ions?

a) addition of $HCl_{(aq)}$
b) stirring the mixture
c) addition of $Cr(OH)_{3(s)}$
d) addition of a small quantity of $KOH_{(s)}$

Q6. Consider the following system:

$$\underset{\text{colourless}}{2NO(g)} + \underset{\text{pale green}}{Cl_2(g)} \longleftrightarrow \underset{\text{red}}{2NOCl(g)} \quad \Delta H \text{ positive}$$

Which of the following is true concerning the above system at equilibrium?

I the rate of the forward reaction equals the rate of the reverse reaction
II addition of a catalyst would make the colour more red
III cooling the system would result in the colour fading
IV addition of chlorine gas would result in the colour becoming more red

a) I and III only
b) I and II only
c) I, III and IV only
d) all of I, II, III and IV

Q7: Methanol can be synthesized from carbon monoxide and hydrogen as illustrated by the equation:

$$2\,H_{2(g)} + CO_{(g)} \leftrightarrows CH_3OH_{(g)} \qquad \Delta H = -92\ kJ$$

Which of the following sets of reaction conditions would maximize the yield of methanol at equilibrium?

a) High temperature, high pressure.
b) High temperature, low pressure.
c) Low temperature, low pressure.
d) Low temperature, high pressure.

Q8. In the Haber process:

$$N_{2(g)} + 3\,H_{2(g)} \leftrightarrows 2\,NH_{3(g)} + \text{heat}$$

an increase in temperature at constant pressure will:

a) increase the $N_{2(g)}$ concentration.
b) increase the ammonia concentration.
c) lower the forward reaction rate.
d) lower the reverse reaction rate.

Q9. Consider the following equation representing the dissolving of the yellow solid calcium chromate:

$$CaCrO_{4(s)} \leftrightarrows Ca^{2+}_{(aq)} + CrO_4^{2-}{}_{(aq)}$$

What would you observe if some concentrated (5 mol L^{-1}) calcium chloride solution was added to a saturated solution of calcium chromate?

a) More yellow solid forms, and the solution would become paler.
b) More yellow solid forms, and the solution would become a darker yellow.
c) The yellow solid dissolves, and the solution would become paler.
d) There is no significant change in appearance.

Q10. The equilibrium constant, K, for the reaction below is equal to 2×10^{81} at 25°C.

$$2H_{2\,(g)} + O_{2\,(g)} \leftrightarrows 2H_2O_{\,(g)}$$

This value suggests that:

(a) this reaction favours the forward reaction slightly more than the reverse reaction.

(b) this reaction favours the reverse reaction slightly more than the forward reaction.

(c) this reaction virtually goes to completion with little reversal.

(d) this reaction virtually does not proceed forward and largely favours the reactants.

END OF SECTION ONE

SECTION TWO: Short Answer Questions **(15 marks)**

Q11. Consider the following equilibrium system used for the industrial preparation of methanol, CH_3OH.

$$CO_{(g)} + 2H_{2(g)} \longleftrightarrow CH_3OH_{(g)} \quad \Delta H = -918 kJ\ mol^{-1}$$

a) Write the expression for the equilibrium constant, K, for the reaction. (1 mark)

b) Discuss the conditions you would choose to maximise the yield of ethanol if you were the chemist in charge of the production. (4 marks)

Q12. Consider the following system at equilibrium at 25°C:

$$\underset{\text{blue}}{[Cu(H_2O)_6]^{2+}(aq)} + 4\,Cl^-(aq) \longleftrightarrow \underset{\text{lime green}}{[CuCl_4]^{2-}(aq)} + 6H_2O(l)$$

a) Write the expression for the equilibrium constant, K, for the reaction. (1 mark)

b) Predict the effect on the concentration of $[CuCl_4]^{2-}_{(aq)}$ and the rate of the forward reaction of the following changes: (2 marks)

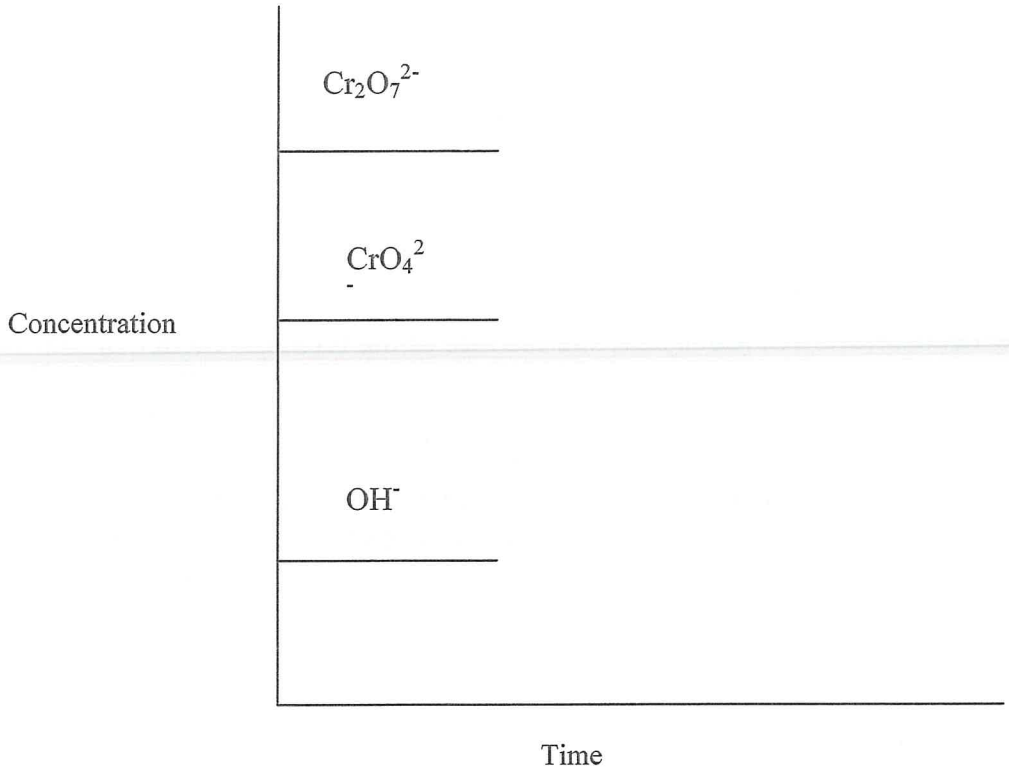
Procedure	Concentration of $[CuCl_4]^{2-}_{(aq)}$	Rate of forward reaction **when equilibrium has been re-established** Write "higher" or "lower"
Addition of $AgNO_3(s)$		

c) Explain your answers to part b) (4 marks)

Q13. Consider the following system at chemical equilibrium:

$$Cr_2O_7^{2-}(aq) + 2OH^-(aq) \longleftrightarrow 2CrO_4^{2-}(aq) + H_2O(l)$$

Sketch a graph of concentration changes if a small quantity of solid potassium dichromate was added to the system. (3 marks)



SECTION THREE: Extended Answer Section **(10 marks)**

Q14. Nitric acid is produced commercially by the Ostwald process represented by the following equations:

$$4NH_{3\,(g)} + 5O_{2\,(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}$$

$$2NO_{(g)} + O_{2\,(g)} \rightarrow 2NO_{2\,(g)}$$

$$3NO2_{(g)} + H_2O_{(l)} \rightarrow 2HNO_{3\,(g)} + NO_{(g)}$$

What mass of NH_3 must be used to produce 1.00×10^6 kg HNO_3 by the Otswald process, assuming 100% yield in each reaction? (4 marks)

Q15. A sample of a mixture of pure sodium sulphate decahydrate ($Na_2SO_4.10H_2O$) and pure copper(II) sulphate pentahydrate ($CuSO_4.5H_20$) is dissolved in water and after thorough stirring, the solution is exactly halved, each half being called an aliquot.

To one aliquot the addition of excess barium chloride results in the formation of 10.740 g of barium sulphate.

Sufficient sodium hydroxide is added to the other aliquot to effect precipitation of insoluble hydroxides. The precipitate is filtered off and strongly heated to yield 1.591 g of a black residue, CuO.

What was the mass of the sample originally taken? (6 marks)

UNIT 3 NAME:_____

REACTION RATES & EQUILIBRIUM TEST 2012

SECTION ONE: Multiple Choice Questions **(10 marks)**

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
A	A	B	D	D	C	D	A	A	C

SECTION TWO: Short Answer Questions **(15 marks)**

Q11. Consider the following equilibrium system used for the industrial preparation of methanol, CH_3OH.

$$CO_{(g)} + 2H_{2(g)} \longleftrightarrow CH_3OH_{(g)} \quad \Delta H = -918 kJ\ mol^{-1}$$

a) Write the expression for the equilibrium constant, K, for the reaction. (1 mark)

$$K = \frac{[CH_3OH]}{[CO][H_2]^2}$$

b) Discuss the conditions you would choose to maximise the yield of ethanol if you were the chemist in charge of the production. (4 marks)

- ↑ pressure - the POE will shift to favour the side with fewer moles of gas.
- ↓ temperature - the POE will shift to favour the forward (exothermic) reaction. However, this ↓ reaction ∴ must use a catalyst.
- Remove $CH_3OH_{(g)}$ from system (ie ↓ $[CH_3OH]$)
- Add $CO_{(g)}$ or $H_{2(g)}$ from system (ie ↑ $[CO]$ or $[H_2]$).

Q12. Consider the following system at equilibrium at 25°C:

$$\underset{\text{blue}}{[Cu(H_2O)_6]^{2+}_{(aq)}} + 4\ Cl^-_{(aq)} \longleftrightarrow \underset{\text{lime green}}{[CuCl_4]^{2-}_{(aq)}} + 6H_2O_{(l)}$$

a) Write the expression for the equilibrium constant, K, for the reaction. (1 mark)

$$K = \frac{[CuCl_4^{2-}]}{[Cu(H_2O_6)^{2+}][Cl^-]^4}$$

b) Predict the effect on the concentration of $[CuCl_4]^{2-}_{(aq)}$ and the rate of the forward reaction of the following changes: (2 marks)

Procedure	Concentration of $[CuCl_4]^{2-}_{(aq)}$	Rate of forward reaction **when equilibrium has been re-established** Write "higher" or "lower"
Addition of $AgNO_3(s)$	decrease	lower

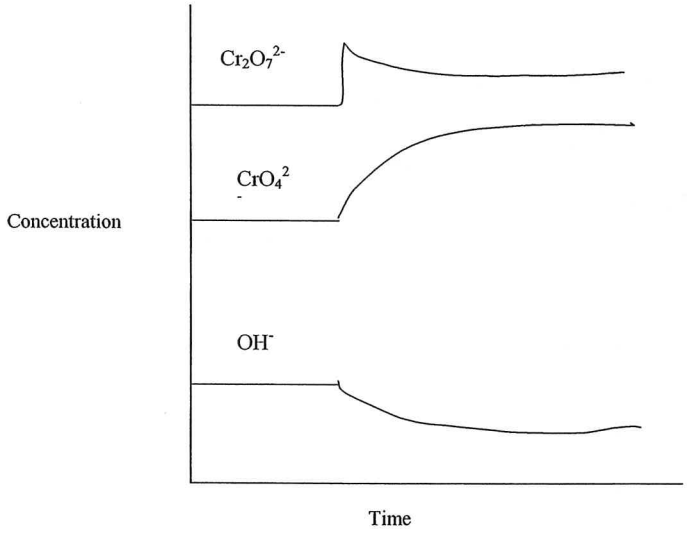
c) Explain your answers to part b) (4 marks)

$AgNO_3(s)$ will produce Ag^+ & NO_3^- ions
(1) The Ag^+ ions will react with the Cl^- ions to form a white ppt ($AgCl$). This lowers
(1) $[Cl^-]$ and according to LCP the POE
(1) will shift left, thus increasing $[Cl^-]$ in order to partially counteract the imposed change. As the equilibrium is shifting left
(1) this lowers $[CuCl_4]^{2-}_{(aq)}$ as the rate of the forward rxn has been decreasing whilst equilibrium is reestablished.

Q13. Consider the following system at chemical equilibrium:

$Cr_2O_7^{2-}(aq) + 2OH^-(aq) \longleftrightarrow 2CrO_4^{2-}(aq) + H_2O(l)$

Sketch a graph of concentration changes if a small quantity of solid potassium dichromate was added to the system. (3 marks)



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$4NH_{3\,(g)} + 5O_{2\,(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}$

$2NO_{(g)} + O_{2\,(g)} \rightarrow 2NO_{2\,(g)}$

$3NO2_{(g)} + H_2O_{(l)} \rightarrow 2HNO_{3\,(g)} + NO_{(g)}$ ← careful!

What mass of NH_3 must be used to produce 1.00×10^6 kg HNO_3 by the Otswald process, assuming 100% yield in each reaction? (4 marks)

$m(NH_3) = ?$ (1)

$12\,NH_3 + 21O_2 \rightarrow 14H_2O + 8HNO_3 + 4NO$

unknown — known

$n(HNO_3) = \frac{m}{MR} = \frac{1 \times 10^9}{63.018} = 15868482.02 \text{ moles}$ (1)

$n(NH_3) = \frac{12}{8} \times n(HNO_3)$

$= \frac{12}{8} \times 15868482.02$

$= 23802723.03$ (1)

★ don't round early!
★ underline answer

$m(NH_3) = n \times MR$

$= 23802723.03 \times 17.034$

$= 405\,455\,841\,g$

$\therefore m(NH_3) = 405\,456\,kg$ (1)

$= 4.05 \times 10^5\,kg$ ★ 3 sig figs

★ notice my answer is in kg .... this is because in the question the mass has been given in kg. BUT all working is done in g.

Q15. A sample of a mixture of pure sodium sulphate decahydrate ($Na_2SO_4.10H_2O$) and pure copper(II) sulphate pentahydrate ($CuSO_4.5H_2O$) is dissolved in water and after thorough stirring, the solution is exactly halved, each half being called an aliquot.

To one aliquot the addition of excess barium chloride results in the formation of 10.740 g of barium sulphate.

Sufficient sodium hydroxide is added to the other aliquot to effect precipitation of insoluble hydroxides. The precipitate is filtered off and strongly heated to yield 1.591 g of a black residue, CuO.

What was the mass of the sample originally taken? (6 marks)

$m(Na_2SO_4 \cdot 10H_2O) = ?$

$n(BaSO_4) = \frac{m}{MR} = \frac{10.74}{233.36} = 0.046023311$ (1)

$n(SO_4^{2-}) = n(BaSO_4)$

$n(CuO) = \frac{m}{MR} = \frac{1.591}{79.5} = 0.020012578$ (1)

$n(CuO) = n(Cu)$

As both solutions have been halved $\therefore \times 2$

$n(SO_4^{2-}) = 0.092046622$

$n(Cu) = 0.040025156$ (1)

$n(Cu) = n(CuSO_4.5H_2O)$

$m(CuSO_4.5H_2O) = n \times MR = 0.040025156 \times 249.69$

$= 9.993889$ (1)

$n(SO_4^{2-}) - n(CuSO_4) = n(Na_2SO_4)$

$0.092046622 - 0.040025156 = 0.052021466$ moles

$m(Na_2SO_4.10H_2O) = n \times MR = 0.052021466 \times 322.2$

$= 16.7613166$ (1)

Total mass $= 9.99 + 16.76$

$= 26.7559$ g (1)

END OF TEST