# THE COLLEGE OF THE BAHAMAS

## EXAMINATION

SEMESTER 01-2007

## FACULTY OF PURE AND APPLIED SCIENCES

SCHOOL OF SCIENCES AND TECHNOLOGY

X NASSAU
FREEPORT
EXUMA
ELEUTHERA

**DATE AND TIME OF EXAMINATION**: Monday, April 16, 2007 at 2 pm
**DURATION: 3 HOURS**

COURSE NUMBER: CHEM 225

COURSE TITLE: COLLEGE CHEMISTRY II

STUDENT NAME:

STUDENT NUMBER:

LECTURER'S NAME

**INSTRUCTIONS TO CANDIDATES**: This paper has 2 pages and 35 questions. Please follow instructions given.

# SECTION I: Multiple Choice Questions

***Select the SINGLE best alternative in each of the following cases and indicate your answer on the answer sheet provided. Answer ALL questions in this section***

1) The equilibrium constant for the reaction
$P(aq) \rightleftharpoons Q(aq)$ is $3.75 \times 10^{-7}$.
Which of the following statements is **TRUE**?
A The equilibrium concentration of P is less than that of Q.
B The equilibrium concentration of P is greater than that of Q.
C Adding a suitable catalyst will increase the equilibrium concentration of P.
D Adding a catalyst will increase the value of the equilibrium constant.
E Adding more P will increase the value of the equilibrium constant.

2) For the reaction
$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$
the rate law is
$R = k[H_2O_2]^2[H^+]$
Which of the following statements is true?
A The rate depends on the concentration of $H_2O_2$, $H^+$ and $I^-$.
B $I^-$ is a catalyst.
C Doubling the concentration of $H_2O_2$ causes the reaction rate to double.
D Doubling the concentration of $H^+$ causes the reaction rate to double.
E $I^-$ is not necessary for the reaction to proceed.

3) Consider the reaction
$NO(g) + O_3(g) \rightleftharpoons NO_2(g) + O_2(g)$
The activation energy for this reaction is 10 kJ, whilst the activation energy for the reverse reaction is 210 kJ. What is the enthalpy change for the forward reaction, in kJ?
A -200
B -210
C -220
D -2000
E -20

4) For the reaction
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
the average rate with respect to the production of ammonia is expressed as
$$\frac{\Delta[NH_3]}{\Delta t}$$
An expression whose value is the same is:

A $\frac{-\Delta[N_2]}{\Delta t}$
B $\frac{\Delta[H_2]}{2\Delta t}$
C $\frac{\Delta[N_2]}{\Delta t}$
D $\frac{\Delta[H_2]}{3\Delta t}$
E $\frac{-2\Delta[N_2]}{\Delta t}$

5) The rate constant (k) for a chemical process can be altered by
A a change in temperature.
B a change in the concentration of the reactants.
C a change in pressure.
D the addition of more reactants.
E the removal of products.

6) For a chemical system in a state of equilibrium which of the following statements is FALSE?
A The equilibrium constant remains the same provided the temperature is constant.
B Reactants and products must all be in the same physical state.
C The rate of the forward reaction is equal to that of the back reaction.
D The equilibrium concentrations of the substances present vary with temperature.
E The reaction quotient (Q) is equal to the equilibrium constant (K).

7) For which system will $K_c$ (equilibrium constant in terms of concentrations) be equal to $K_p$ (equilibrium constant in terms of partial pressures)?
A $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
B $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$
C $2H_2O(l) \rightleftharpoons 2H_2(g) + O_2(g)$
D $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$
E $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$

8) When iron and steam are placed in a closed container at 700°C, the following equilibrium is set up:
$3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$ $\Delta H$ = -ve
The amount of hydrogen present at equilibrium can be increased by
A adding more $Fe_3O_4$.
B decreasing the temperature to 600°C.
C adding an inert gas at constant volume.
D increasing the temperature to 800°C.
E increasing the mass of iron.

9) The hydronium ion ($H_3O^+$) concentration of a solution consisting of a weak acid (HA) in aqueous solution together with its sodium salt ($Na^+A^-$) is given by
A $[H_3O^+] = K_a[A^-]$
B $[H_3O^+] = K_a[HA]$
C $[H_3O^+] = K_a[A^-] + [HA]$
D $[H_3O^+] = K_a[HA]/[A^-]$
E $[H_3O^+] = K_a[A^-]/[HA]$

10) Two aqueous solutions, one of a monoprotic strong acid and the other of a monoprotic weak one, have the same concentration. Equal volumes of each are titrated with sodium hydroxide solution of a certain molarity. Which of the following statements is true?
   A The titre value for the strong acid is the larger.
   B The titre value for the weak acid is the larger.
   C The two acids will give equal titre values.
   D The relative sizes of the titre values cannot be predicted from the above information.
   E The strong acid cannot have the same concentration as the weak acid.

11) Which indicator is most suitable for detecting the end-point of the titration of ethanoic acid with sodium hydroxide, given that at the equivalence point the solution only contains sodium ethanoate (also known as sodium acetate)?

| | INDICATOR | pH RANGE |
|---|---|---|
| A | thymol blue | 1·2 to 1·8 |
| B | methyl orange | 3·1 to 4·4 |
| C | methyl red | 4·2 to 6·2 |
| D | bromothymol blue | 6·0 to 7·6 |
| E | phenolphthalein | 8·3 to 10·0 |

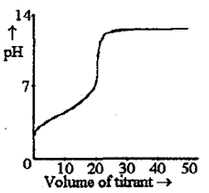
12) Which of the following does NOT change the equilibrium position of the system
$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ $\Delta H$ +ve?
   A Increasing the mass of calcium carbonate.
   B Increasing the temperature.
   C Decreasing the temperature.
   D Increasing the volume of the containing vessel.
   E Adding some carbon dioxide gas without changing the volume of the containing vessel.

13) Arsenic acid, $H_3AsO_4$ is a triprotic acid. The dissociation constant, $K_{a1}$ for the first step of dissociation
$H_3AsO_4(aq)+H_2O(l) \rightleftharpoons H_2AsO_4^-(aq)+H_3O^+(aq)$
is $6{\cdot}5 \times 10^{-3}$. The dissociation constant, $K_{a2}$, for the second step is most likely to be
   A $6{\cdot}5 \times 10^{-3}$
   B $1{\cdot}1 \times 10^{-2}$
   C $6{\cdot}5 \times 10^{-2}$
   D $3{\cdot}6 \times 10^{-1}$
   E $8.3 \times 10^{-8}$

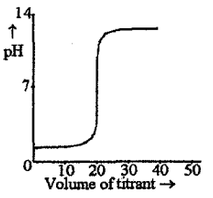
14) Which one of the following pairs of species is an acid-base conjugate pair?
   A $H_3O^+$ and $OH^-$
   B $CH_3NH_4^+$ and $CH_3NH_2$
   C $H_2PO_4^-$ and $HPO_4^{2-}$
   D $H_3PO_4$ and $PO_4^{3-}$
   E $CO_2$ and $H_2CO_3$

***Questions 15-19. The diagrams A to E represent titration curves for the reaction between various acids and bases.***

A




B

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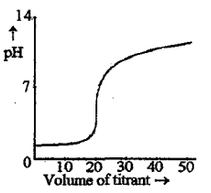
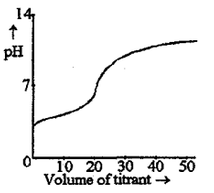
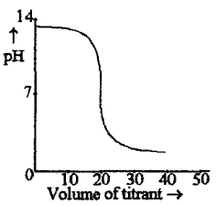



D




E




***Given that each curve may be used once, more than once or not at all, choose from A to E the curve which best represents each of the following.***

15) The titration of 20 $cm^3$ of 0·1 M HCl with 0·1 M NaOH.
16) The titration of 20 $cm^3$ of 0·1 M $CH_3COOH$ with 0·1 M NaOH.
17) The titration of 20 $cm^3$ of 0·1 M $CH_3COOH$ with 0·1 M $NH_3$.
18) The titration of 20 $cm^3$ of 0·1 M NaOH with 0·1 M HCl.
19) The titration of 20 $cm^3$ of 0·1 M HCl with 0·1 M $NH_3$.

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20) The $pK_a$ values for three acids P, Q, and R are 5·2, 4·8 and 3·4 respectively. It follows that
   A R is the weakest acid.
   B P has the largest $K_a$ value.
   C The basicity constant of the conjugate base of Q is $10^{-4.8}$.
   D Q is stronger than P.
   E The conjugate base of P is strong.

21) When the contents of an electrochemical cell are at equilibrium:
   A The e.m.f. of the cell is zero.
   B The e.m.f. of the cell is negative.
   C The e.m.f. of the cell is positive.
   D The e.m.f. of the cell cannot be measured.
   E The e.m.f. of the cell is at a maximum.

***Questions 22 to 24 involve the following data for the electrode potentials of three metals in water and liquid ammonia.***

| Electrode | $E^{\ominus}$ ($H_2O$)/V | $E^{\ominus}$ ($NH_3$)/V |
|---|---|---|
| $K^+/K$ | -2·93 | -1·98 |
| $Ca^{2+}/Ca$ | -2·87 | -1·74 |
| $Na^+/Na$ | -2·71 | -1·85 |

22) In ammonia the strongest reducing agent is
A sodium
B calcium ions
C calcium
D potassium ions
E potassium

23) Each of the metals is a
A weaker reducing agent in ammonia than in water.
B weaker reducing agent in water than in ammonia.
C weaker oxidising agent in ammonia than in water.
D weaker oxidising agent in water than in ammonia.
E No such generalisation can be made.

24) The standard e.m.f. of the cell
$Na(s)\,|\,Na^+(aq)\,\|\,Ca^{2+}(NH_3)\,|\,Ca(s)$
should be
A +0·97V
B -0·97V
C +0·11V
D -0·11V
E +0·16V

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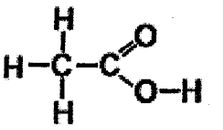
25) According to the Brønsted-Lowry definition, an acid is a species which donates a
A hydrogen atom.
B hydrogen ion.
C hydrogen molecule.
D hydride ion.
E hydroxide ion.

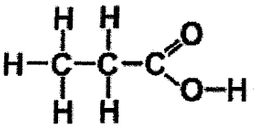
***Questions 26 to 27 concern various acids. Using the rules that relate acid strength to structure, pick the strongest acid in each case.***

26) **A** $HClO$ **B** $HClO_2$ **C** $HClO_3$
**D** $HClO_4$ **E** $HBrO$

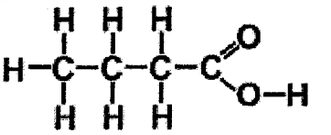
27) **A**



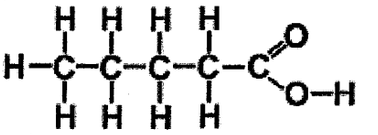
**B**



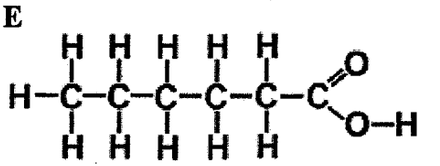
**C**



**D**



**E**



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28) Which one of the following equations represents a redox reaction?
A $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
B $PCl_5(aq) + H_2O(l) \rightarrow POCl_3(l) + 2H^+(aq) + 2Cl^-(aq)$
C $Cu^{2+}(aq) + 4Cl^-(aq) \rightarrow [CuCl_4]^{2-}(aq)$
D $[Fe(CN)_6(aq) + \frac{1}{2}Cl_2(g) \rightarrow [Fe(CN)_6]^{3-}(aq) + Cl^-(aq)$
E $CH_3COOH(aq) + H_2O(l) \rightarrow CH_3COO^-(aq) + H_3O^+(aq)$

29) Which half-reaction correctly represents reduction?
A $Cr_2(g) \rightarrow 2Cr(g)$
B $Cr^{3+} \rightarrow Cr(s) + 3e^-$
C $Cr(s) \rightarrow Cr^{3+} + 3e^-$
D $Cr(s) + 3e^- \rightarrow Cr^{3+}$
E $Cr^{3+} + 3e^- \rightarrow Cr(s)$

30) Which quantities are conserved in all redox reactions?
A charge only
B mass only
C oxidation number
D neither charge nor mass
E both charge and mass

**SECTION II: Structured Questions.** ***Answer* ALL *of the following questions in the spaces provided on the question paper. Underline numerical answers and express them to the correct number of figures. Brief details of working must be included even when they are not asked for specifically. Clarity of expression is of the highest importance.***

1) For the reaction

$$2NO(g) + H_2(g) \rightarrow N_2O(g) + H_2O(g)$$

the following experimental rate data are collected in three experiments carried out at the same temperature.

| INITIAL [NO] /M | INITIAL [$H_2$] /M | INITIAL RATE OF $N_2O$ FORMATION /M $min^{-1}$ |
|---|---|---|
| 0·60 | 0·37 | 0·18 |
| 1·20 | 0·37 | 0·72 |
| 1·20 | 1·11 | 2·16 |

a) Write a rate law for the reaction. (2)

b) Why is it necessary to carry out the three experiments at the same temperature? (1)

c) Calculate the rate constant for the reaction. (2)

d) Calculate the initial rate of formation of $N_2O$ when the concentration of NO is 0.50 M, and the concentration of $H_2$ is 0.40 M. (2)

e) Calculate the initial rate of consumption of NO when the initial rate of formation of $N_2O$ is 2.16 M $min^{-1}$. (2)

2) a) Define pH. (1)

b) Write an expression to define the *ionic product* of water. State its value at 25°C. (2)

c) Calculate the pH of each the following solutions at 25°C.

i) $2{\cdot}00 \times 10^{-3}$ M hydrochloric acid (1)

ii) $2{\cdot}00 \times 10^{-3}$ M potassium hydroxide (2)

iii) a mixture which is prepared by adding 30·0 $cm^3$ of 0·10 M HCl to 20·0 $cm^3$ of 0·10 M KOH. (2)

iv) 0·55 M $CH_3COOH(aq)$, $K_a = 1{\cdot}76 \times 10^{-5}$ (6)

d) For each salt given, state whether you expect its solution to have a pH greater than 7, less than 7, or approximately 7. (HCN is a weak acid and $NH_3$ is a weak base.) Wherever a hydrolysis reaction occurs, write an equation for the hydrolysis reaction. If there is none, write "NONE". (8)

| SALT | pH | HYDROLYSIS REACTION |
|---|---|---|
| $KNO_3$ | | |
| KCN | | |
| $NH_4Cl$ | | |
| $Al(NO_3)_3$ | | |

3) The solubility product of $Ca(OH)_2$ is $5{\cdot}5\times10^{-6}$ at 25°C.

a) Find the molar solubility of $Ca(OH)_2$ in water at 25°C. (4)

b) Find the molar solubility of $Ca(OH)_2$ in 0.010 M $Ca(NO)_3$(aq) at 25°C. (5)

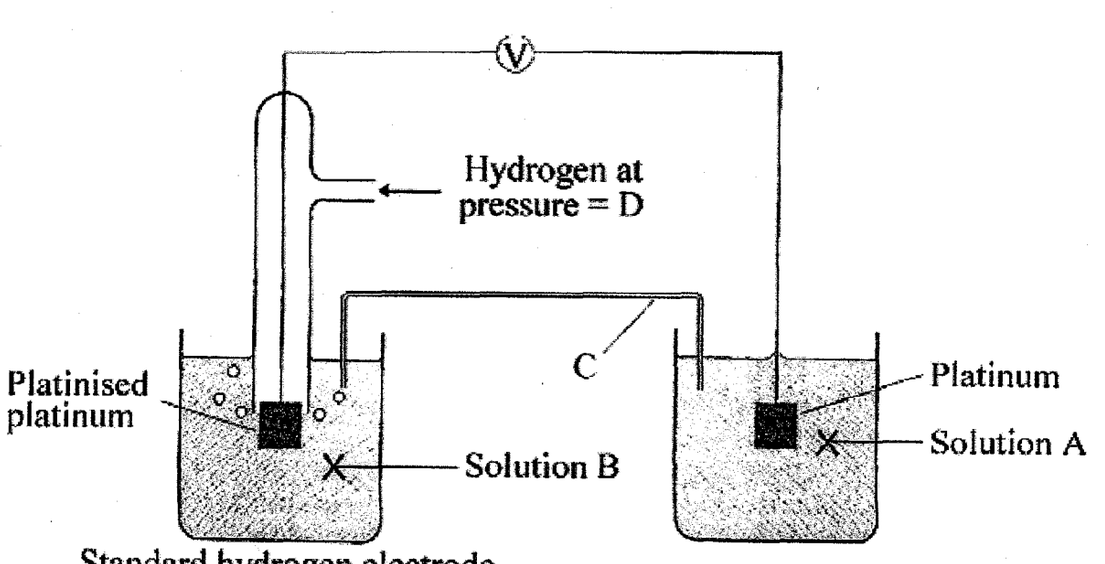
c) Explain why the solubility of calcium hydroxide increases as the pH of the solution decreases. (3)

4) The following is a list of standard redox potentials.

| | $E^{\theta}$/V |
|---|---|
| $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$ | 1·51 |
| $Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$ | 1·36 |
| $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ | 1·33 |
| $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ | 0·77 |
| $2H^+(aq) + 2e^- \rightarrow H_2(g)$ | 0.00 |

This question is about electrode potentials.

a) The incompletely labelled diagram shows an experimental arrangement by which the standard electrode potential of the $Fe^{3+}/Fe^{2+}$ couple may be determined.



What is represented by each of the labels A to C? (Give concentrations where appropriate.) (6)

A: _____

B: _____

C: _____

D: What is the value of D? _____

b) Mark on the diagram
   i) the anode. (1)
   ii) the direction of electron flow in the external circuit. (1)

c) Write a *cell diagram* to represent the cell. (2)

_____

d) Calculate the standard e.m.f. of the cell. (1)

e) Write an equation to represent the reaction taking place in the cell. (1)

_____

f) Under what (non-standard) conditions would the cell potential be reduced to zero? (1)

_____

_____

g) By reference to the standard electrode potentials given above, explain why hydrochloric acid can be used to provide an acid medium with potassium dichromate but **NOT** with potassium manganate(VII) as oxidizing agents. (Hint: consider oxidation of the chloride ion to chlorine.) (4)

_____

_____

_____

_____

_____

_____

5) Give careful and complete descriptions of SIX of the following terms: (6)
   a) Brønsted-Lowry acid.

_____

_____

_____

b) Anode.

c) Equivalence point.

d) End-point.

e) Polyprotic acid.

f) Hydrolysis.

g) Hydration shell.

h) Buffer solution.

i) Acid/base indicator.