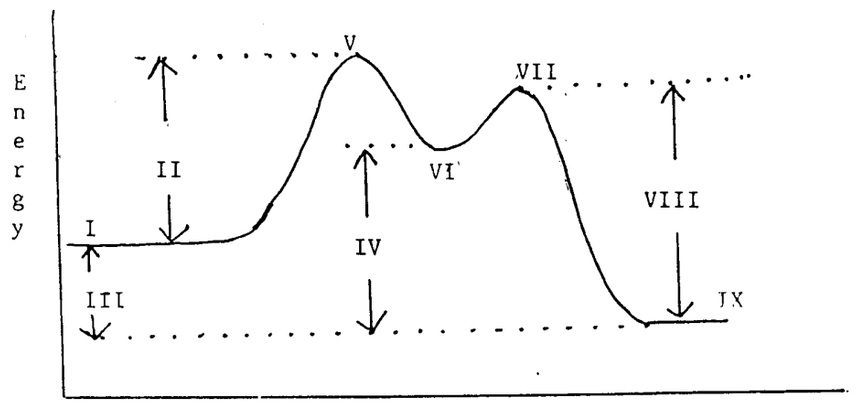
Section A: Multiple choice questions.[1 mark each = 35 marks].

Answer **ALL** questions. For each question, select the best answer and shade the letter corresponding to this answer on the answer sheet provided.

Questions 1-5 concern the following diagram. This shows the energy profile for a reaction.



1. Which of the following conclusions can be drawn from this diagram?

a) the reaction is endothermic.
b) the reaction involves one transition state.
c) the first step is slower than the second step.
d) the reaction involves two intermediates.
e) the activation energy for the first step is lower than the activation energy for the second step.

2. Which of the following labels correctly indicates the enthalpy change for the reaction?

a) II
b) III
c) VII
d) VIII
e) IX

3. Which one of the following labels correctly indicates a reaction intermediate?

a) I
b) IV
c) V
d) VI
e) VII

4. Which of the following labels correctly indicates a transition state?

a) I
b) IX
c) V
d) VIII
e) VI

5. Which of the following labels correctly indicates the activation energy for the first step of the reverse reaction?

a) II
b) III
c) IX
d) VII
e) VIII

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6. Dinitrogen pentoxide (N_2O_5) decomposes in CCl_4 according to the equation:
$2N_2O_5 \rightarrow 4NO_2 + O_2$
If the rate of consumption of N_2O_5 is 4.0×10^{-4} Ms^{-1}, then the rate at which

a) NO_2 is formed is 2.0×10^{-4} Ms^{-1}
b) NO_2 is formed is 4.0×10^{-4} Ms^{-1}
c) O_2 is formed is 1.0×10^{-4} Ms^{-1}
d) O_2 is formed is 4.0×10^{-4} Ms^{-1}
e) O_2 is formed is 2.0×10^{-4} Ms^{-1}

7. Which of the following is most likely to be the rate determining step of a reaction?

a) The unimolecular step.
b) The bimolecular step.
c) The first step.
d) The fastest step.
e) The slowest step.

8. 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 reaction rate at a given temperature depends on the concentration of I^- only.
b) I^- is a catalyst since it does not appear in the rate equation.
c) Doubling the concentration of H_2O_2 would cause the reaction rate to quadruple at a given temperature.
d) Halving the concentration of H^+ would cause the reaction rate to double at a given temperature.
e) I^- is not necessary for the reaction to take place.

9. Which statement is **false**?

a) A reversible system is in dynamic equilibrium when the rate of the forward reacti is equal to the rate of the backward reaction.
b) A homogeneous system in equilibrium has all the components in the same phase.
c) When a reversible system is in equilibrium, the concentration of each substance i the system remains constant.
d) When a reversible system is in equilibrium, Q = K.
e) The concentration of each component in a K_c expression is its initial concentratic

10. At 360 K, $K_p = 0.8$ for the process: $A(g) + B(g) \rightleftharpoons AB(g)$.
At the same temperature, the value of K_c is

a) 23.6
b) 2.2
c) 21.6
d) 0.027
e) 5.71

11. For the reaction: $2AB(g) \rightleftharpoons A_2(g) + B_2(g)$, $K_c = 1.45 \times 10^{-3}$. What is K_c for the reaction $\frac{1}{2} A_2(g) + \frac{1}{2} B_2(g) \rightleftharpoons AB(g)$?

a) 1.45×10^{-3}
b) 689.7
c) 26.26
d) 7.25×10^{-4}
e) 2.10×10^{-6}

12. Which statement about catalysts is **not** true?

a) Catalysts are specific in their action.
b) A catalyst lowers E_a for the forward and reverse processes by the same amount.
c) A catalyst does not affect the position of equilibrium.
d) A catalyst is always in the same phase as the reactants.
e) A catalyst changes the rate at which a system reaches equilibrium.

13. When iron and steam are placed in a closed container at 500 K, the following equilibrium is set up:
$3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$ $\quad H = -q$ kJ
The partial pressure of hydrogen can be increased by

a) increasing the volume of the containing vessel.
b) decreasing the temperature to 250 K.
c) adding an inert gas at constant volume.
d) increasing the temperature to 700 K.
e) increasing the mass of iron.

14. For which reversible system at equilibrium would a change in volume of the containing vessel **not** affect equilibrium position?

a) $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$
b) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
c) $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$
d) $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$
e) $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$

15. The $[OH^-]$ in 2.0×10^{-4} M hydrochloric acid is, in $moldm^{-3}$,

a) 2.0×10^{-4}
b) 1.0×10^{-4}
c) 5.0×10^{-11}
d) 10.3
e) 3.7

16. Which of the following salts would produce a solution with the **highest** pH? Assume all solutions are the same molar concentration.

a) NaCl
b) NaClO
c) NH_4Cl
d) $FeCl_2$
e) $FeCl_3$

17. Which is **not** a strong acid?

a) HNO_2
b) HCl
c) HNO_3
d) $HClO_4$
e) HBr

18. Which is the **strongest** acid?

a) HF
b) HCl
c) HBr
d) HI
e) H_2O

19. The pK_a for an acid, HA, is 5.2. K_b of its conjugate base, A^-, is closest to

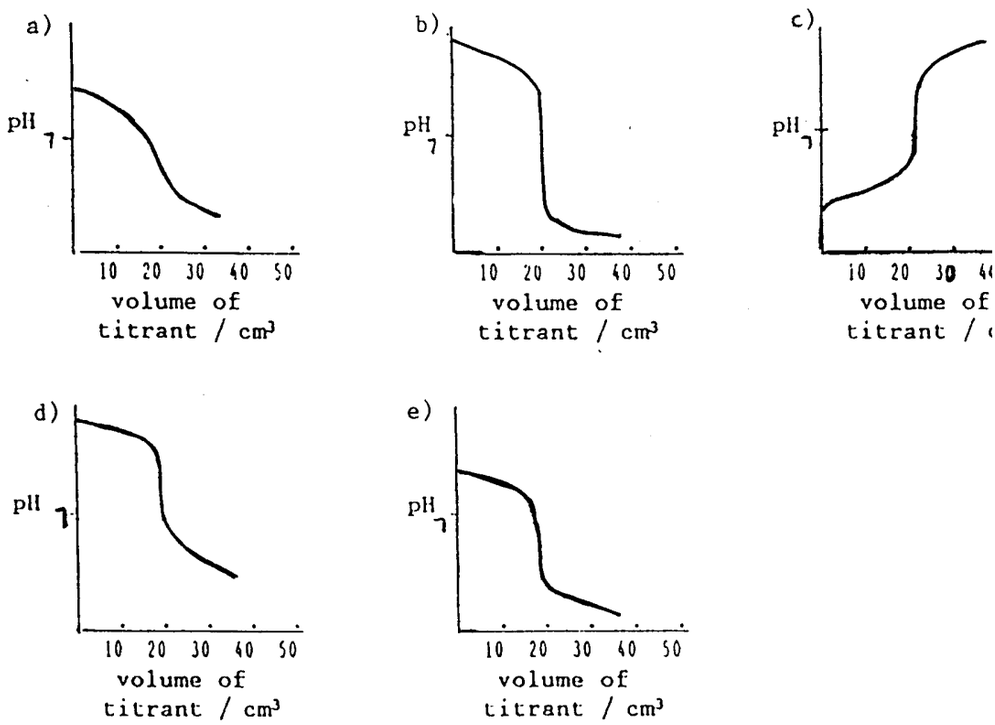
a) 8.8
b) l4
c) 1.6×10^{-9}
d) 6.3×10^{-6}
e) 1.0×10^{-14}

20. The pH of pure water at temperature T ^{0}C is 6.0. Which statement is true? At T ^{0}C
a) pure water is acidic
b) the $[H^+]$ in pure water is 1.0×10^{-7} M.
c) K_w is 1.0×10^{-12}
d) K_w is 1.0×10^{-6}
e) the $[OH^-]$ in pure water is 1.0×10^{-8} M.

21. Which of the following mixtures will give a solution of pH **greater** than 7 ?

a) 20 cm^3 of 0.1 M HCl + 20 cm^3 of 0.1 M Na_2CO_3
b) 20 cm^3 of 0.1 M H_2SO_4 + 20 cm^3 0f 0.1 M NaOH
c) 20 cm^3 of 0.1 M H_2SO_4 + 40 cm^3 of 0.1 M NaOH
d) 20 cm^3 of 0.1 M CH_3COOH + 20 cm^3 of 0.1 M NaOH
e) 20 cm^3 of 0.1 M HCl + 20 cm^3 of 0.1 M NH_3

Questions 22-26. The diagrams A to E represent titration curves for the reaction between various acids and bases.



Choose from A to E the curve which best represents

22) the titration of 20 cm^3 of 0.1M NaOH with 0.1M HCl.
23) the titration of 20 cm^3 of 0.1M NaOH with 0.1M CH_3COOH.
24) the titration of 20 cm^3 of 0.1M NH_3 with 0.1M CH_3COOH.
25) the titration of 20 cm^3 of 0.1M CH_3COOH with 0.1M NaOH.
26) the titration of 20 cm^3 of 0.1M NH_3 with 0.1M HCl.

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27. Which indicator is most suitable for detecting the end-point of the titration of nitri acid with sodium hydroxide?

	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

Questions 28 - 29. The solubility product of silver chloride (AgCl) is 2.0×10^{-10}.

28. The molar solubility of silver chloride in water is

a) 1.4×10^{-5}
b) 2.0×10^{-10}
c) 4.0×10^{-20}
d) 1.0×10^{-10}
e) 3.6×10^{-4}

29. The molar solubility of silver chloride in 0.1 M NaCl is

a) 2.0×10^{-10}
b) 1.0×10^{-10}
c) 2.0×10^{-9}
d) 1.4×10^{-5}
e) 3.6×10^{-4}

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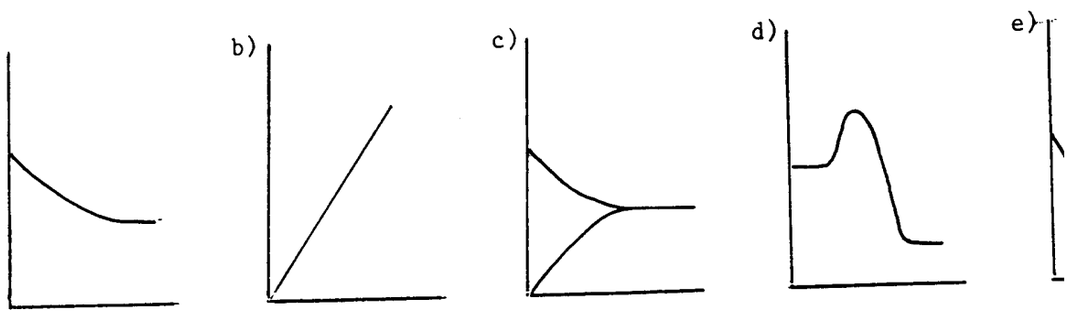
30. Which is **not** a redox reaction?

a) $CaCO_3\,(s) \rightarrow CaO\,(s) + CO_2\,(g)$
b) $2SO_2\,(g) + O_2\,(g) \rightarrow 2SO_3\,(g)$
c) $2Ag\,(s) + Cl_2\,(g) \rightarrow 2AgCl\,(s)$
d) $2HCl\,(aq) + Zn\,(s) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$
e) $CuSO_4\,(aq) + Zn\,(s) \rightarrow ZnSO_4\,(aq) + Cu\,(s)$

31. Which species shows chlorine in its **lowest** oxidation state?

a) NaCl
b) NaClO
c) $NaClO_2$
d) $NaClO_3$
e) Cl_2

Questions 32-35 concern the following sketches of graphs.



Select, from A to E, the graph which best represents

32. Reaction rate versus time for a reversible system which reaches equilibrium aft some time.
33. Concentration of a reactant versus time for a process which goes to completio
34. Concentration of a reactant versus time for a reversible process which reaches equilibrium after some time.
35. Reaction rate versus concentration of X for a process which is first order in X.

SECTION B: STRUCTURED QUESTIONS

Answer **ALL** questions in the spaces provided on the question paper.

1. For the reaction $2ClO_2(aq) + 2OH^-(aq) \rightarrow ClO_3^-(aq) + ClO_2^-(aq) + H_2O(l)$ the following experimental rate data were collected in three experiments carried out at the same temperature.

Experiment	Initial $[ClO_2]$/ M	Initial $[OH^-]$/ M	Initial rate of ClO_3^- formation/ M s^{-1}
1	1.5×10^{-2}	1.5×10^{-2}	3.88×10^{-4}
2	3.0×10^{-2}	1.5×10^{-2}	1.55×10^{-3}
3	1.5×10^{-2}	3.0×10^{-2}	7.76×10^{-4}

a) Write a rate law for the reaction. [1 mark]

b) Find the value of the rate constant, k. [1 mark]

c) Why was it necessary to carry out the three experiments at the same temperature? [1 mark]

d) What is the rate of ClO_2 consumption in experiment 1? [1 mark]

e) Find the rate of the reaction the instant 20 cm^3 of 0.10 M ClO_2 is mixed with 30 cm^3 of 0.40 M OH^- [2 marks]

2. At 298 K, K_c for the reaction: $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$ is 4.61×10^{-3}.
A sample containing 0.065 mol of N_2O_4 is introduced into a 1.0 dm^3 vessel and is allowed to come to equilibrium with NO_2 at 298 K.

a] Find the molar concentration of each gas at equilibrium. [4 marks]

b] Find the % dissociation of the N_2O_4. [1 mark]

3. a) Write an expression for the ionic product of water. What is its accepted value at 298K? [1 mark]

b) What is the pH of the following solutions at 298K?

i) 2.0×10^{-3} M nitric acid [1 mark]

ii) 2.0×10^{-3} M potassium hydroxide [1 mark]

iii) A mixture which is prepared by adding 10 cm^3 of 0.10 M HNO_3 tc 30 cm^3 of 0.10 M NaOH. [2 marks]

iv) A mixture which is prepared by adding 20 cm^3 of 0.10 M KOH to 20 cm^3 of 0.10 M CH_3COOH. $K_a(CH_3COOH) = 1.8 \times 10^{-5}$ [4 marks

v) A mixture prepared by adding 20 cm^3 of 0.10 M KOH to 30 cm^3 c 0.10 M CH_3COOH. $K_a(CH_3COOH) = 1.8 \times 10^{-5}$ [4 marks]

4. The pH of a saturated solution of iron(II) hydroxide, $Fe(OH)_2$, is 9.2 at 25°C.

a) i) Find the molar solubility of $Fe(OH)_2$ in water at 25°C. [2 marks]

ii) What is the solubility product of iron(II) hydroxide at 25°C? [2 marks]

b) Decide whether a precipitate of iron(II)hydroxide would be formed by mixing 5 cm^3 of 0.001M $Fe(NO_3)_2$ and 5 cm^3 of 0.001M NaOH. Show your reasoning. [2 marks]

5. Balance the following redox equations by writing ionic half equations, then combining them.

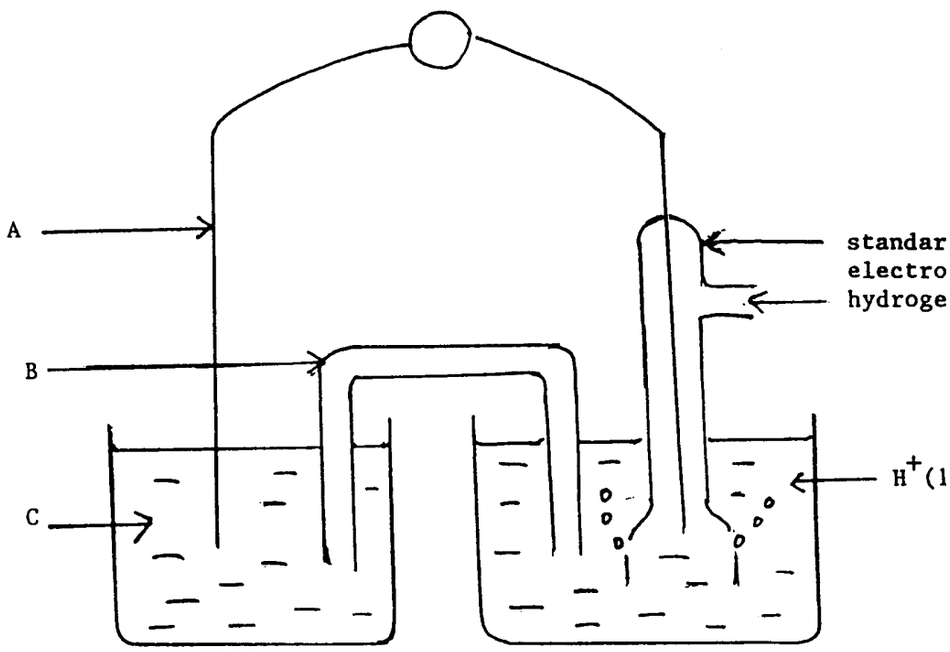
a) $PbS\,(s) + NO_3^-\,(aq) \rightarrow S\,(s) + Pb^{2+}\,(aq) + NO\,(g)$ (in acid medium) [3 marks]

b) $MnO_4^-\,(aq) + IO_3^-\,(aq) \rightarrow MnO_2\,(s) + IO_4^-\,(aq)$ (in basic medium) [3 marks]

6. The following is a list of standard redox potentials.

	E°/V
$MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightarrow Mn^{2+}(aq) + 4\ H_2O(l)$	1.51
$Cl_2(g) + 2\ e^- \rightarrow 2\ Cl^-(aq)$	1.36
$Cr_2O_7^{2-}(aq) + 14\ H^+(aq) + 6\ e^- \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$	1.33
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	0.77
$2H^+(aq) + 2\ e^- \rightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2\ e^- \rightarrow Fe(s)$	-0.44

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



a) What is represented by A to C? [3 marks]

A._____

B._____

C._____

b) What is the value of D?_____ [1 mark]

c) Mark on the diagram

i) the positive pole of the cell . [1 mark]

ii) the direction of electron flow in the external circuit. [1 mark]

d) Write a cell notation to represent the cell. [2 marks

e) What is the e.m.f. of the cell? [1 mark]

c) Write an equation to represent the reaction taking place in the cell. [2 marks]

g) Under what conditions would the cell potential be reduced to zero? [1 mark]

h) By reference to the standard electrode potentials given, explain why hydrochlori acid can be used to provide an acid medium with potassium dichromate but NO with potassium manganate (VII) as oxidizing agents. [2 mark

END OF EXAMINATION.