SECTION A: Multiple Choice [1 mark each = 35 marks]

Each question is followed by five suggested answers. Select the best answer and shade the letter corresponding to this answer on the answer sheet provided.

1. Ammonia can be oxidized according to the equation:
$4\ NH_3\ (g) + 5\ O_2\ (g) \rightarrow 4\ NO\ (g) + 6\ H_2O\ (g)$
If in a particular reaction the $\Delta[O_2]$ is -0.008 mol dm^{-3}, then Δ[NO], in mol dm^{-3} is

A $-5/4 \times 0.008$
B $5/4 \times 0.008$
C $-4/5 \times 0.008$
D $4/5 \times 0.008$
E $4 \times 5 \times 0.008$

Questions 2 and 3 The reaction $2H_2(g) + 2NO(g) \rightarrow 2H_2O(g) + N_2(g)$ is first order in hydrogen and second order in nitrogen monoxide.

2. If the rate of the reaction is expressed in M s^{-1}, the correct unit for the rate constant, k, is

A $M^{-2}\ s^{-1}$
B $M^{2}\ s^{-1}$
C $M\ s^{-1}$
D $M^{-2}\ s^{-2}$
E $M\ s^{2}$

3. In a particular experiment, the rate of formation of nitrogen was 0.004 M s^{-1}. What would be the rate of formation of nitrogen, in Ms^{-1}, if the concentration of hydrogen is halved and that of nitrogen monoxide is doubled?

A 0.002
B 0.004
C 0.008
D 0.012
E 0.016

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4. The energy of activation for a process can be decreased by

A increasing the temperature.
B decreasing the concentrations of the reactants.
C decreasing the total volume of the reacting mixture.
D increasing the total volume of the reacting mixture.
E using a suitable catalyst.

5. The following mechanism has been proposed for a reaction.
Step (a) $NO_2(g) + F_2(g) \rightarrow NO_2F(g) + F(g)$ slow
Step (b) $NO_2(g) + F(g) \rightarrow NO_2F(g)$ fast

Which statement is **NOT** consistent with this proposed mechanism?

A The overall reaction is $2NO_2(g) + F_2(g) \rightarrow 2NO_2F(g)$
B F is a reaction intermediate.
C The reaction is second order.
D The energy of activation for step (a) is higher than that for step (b).
E The rate law for the reaction is $R = k[NO_2]^2[F_2]$

6. The following elementary steps have been proposed for a reaction.

a) $2Co^{2+} + H_2O + OCl^- \rightarrow 2Co^{3+} + 2OH^- + Cl^-$

b) $2Co^{3+} + 2OH^- \rightarrow 2Co^{2+} + H_2O + \frac{1}{2} O_2$

The catalyst in this process is

A Co^{2+}
B Co^{3+}
C Cl^-
D OCl^-
E OH^-

7. 0.12 mol of SO_2 and 0.10 mol of O_2 were introduced into a 1 dm^3 vessel at constant temperature. When the system reached equilibrium, 0.08mol of SO_3 was present. The reaction is: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$.
Which set of values shows the concentration of each gas at equilibrium?

	$[SO_2]$/moldm^{-3}	**$[O_2]$/moldm^{-3}**	**$[SO_3]$/moldm^{-3}**
A	0.04	0.06	0.08
B	0.04	0.02	0.08
C	0.08	0.06	0.08
D	0.02	0.03	0.04
E	0.02	0.15	0.04

8. At a given temperature, T, some PCl_5, at an initial concentration of 1.0 M, was placed in a container and allowed to reach equilibrium. It was found that the PCl_5 was 20% dissociated into PCl_3 and Cl_2 at equilibrium.
K_c for the process: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ at temperature, T, is

A 0.20
B 0.025
C 0.05
D 3.20
E 4.0

9. At 298K, K_c for the process $Si(s) + O_2(g) \rightleftharpoons SiO_2(s)$ is $2x10^{142}$.
Which of the following **CANNOT** be deduced from the data?

A $K_c = 1/[O_2]$
B Equilibrium position lies far to the right.
C When silicon and oxygen react, the limiting reagent is almost completely used up.
D The rate of the reaction between silicon and oxygen to form silicon dioxide is extremely fast.
E K_p for the reverse process is pO_2.

10. The equilibrium constant for the reaction $P(aq) \rightleftharpoons Q(aq)$ is $3.75x10^{-7}$.
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.

11. Which of the following **CANNOT** upset the equilibrium position of the system $NH_4Cl\,(s) \rightleftharpoons NH_3\,(g) + Cl_2\,(g)$?

A Increasing the mass of ammonium chloride.
B Increasing the temperature.
C Decreasing the temperature.
D Increasing the volume of the containing vessel.
E Adding some chlorine gas without changing the volume of the containing vessel.

12. Consider the process $C_2H_4\,(g) + H_2\,(g) \rightleftharpoons C_2H_6\,(g)$ $\Delta H = -137$ kJ at equilibrium.
The value of K_c can be increased by

A Using a suitable catalyst.
B Adding some H_2 to the equilibrium mixture.
C Increasing the concentration of C_2H_6.
D Decreasing the temperature.
E Decreasing the volume of the container.

13. When the system: $NH_4CONH_2\,(s) \rightleftharpoons 2NH_3\,(g) + CO\,(g)$ is at equilibrium at 298K, the total pressure is 0.114atm. K_p for the system is

A 0.038
B 0.076
C 1.48×10^{-3}
D 3.51×10^{-3}
E 2.19×10^{-4}

14. For the reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, $K_p = 1.7$ at 298K. Five systems were set up with the initial partial pressure of each gas as shown in the table. In which system would the **reverse** reaction occur to establish equilibrium?

	Initial partial pressure /atm		
	PCl_5	PCl_3	Cl_2
A	1	1	1
B	2	2	2
C	1	0.5	1.5
D	2	2	1
E	3	2	2

15. According to the Bronsted-Lowry definition, an **acid** is a substance which donates a
A hydrogen atom.
B hydrogen ion.
C hydrogen molecule.
D hydride ion.
E hydroxide ion.

16. Which does **NOT** constitute an acid/base conjugate pair?

A H_2SO_4 / SO_4^{2-}
B NH_3 / NH_2^-
C NH_4^+ / NH_3
D H_3O^+ / H_2O
E HNO_2 / NO_2^-

17. Which is **NOT** a strong acid?
A HCl
B $HClO_4$
C HNO_3
D HNO_2
E HI

18. Which set shows the substances in order of **increasing** acid strength?
    A $HClO_4$, $HClO_3$, $HClO_2$
    B H_2SO_4, H_2SO_3, HSO_4^-
    C HCl, HBr, HF
    D HF, H_2O, NH_3
    E HPO_4^{2-}, $H_2PO_4^-$, H_3PO_4

19. The acidity constant for an acid , HA, is 3.5×10^{-6}. The pK_b of its conjugate base is
A 5.5
B 8.5
C 2.9×10^{-9}
D 1.0×10^{-14}
E 14

20. Which salt would be expected to produce a solution with the **lowest** pH? Assume all solutions have the same molar concentration.
A NaCl
B $MgCl_2$
C $CrCl_3$
D $CaCl_2$
E $BaCl_2$

21. Which statement is usually true of an acid/base indicator?
A It is neither an acid nor a base.
B It always changes colour at pH 7.
C It always changes colour at a pH above 7.
D It always changes colour at a pH below 7.
E It is at the mid point of its colour change when pH = pK of the indicator.

Questions 22 to 27 refer to the following solutions.

A $1x10^{-4}$ M $HClO_4$
B $1x10^{-4}$ M NaOCl
C $1x10^{-4}$ M $FeCl_3$
D $1x10^{-4}$ M NaCl
E $1x10^{-4}$ M NaOH

Select from A to E,

22. The solution which would have the lowest pH.
23. The solution which would have the highest pH.
24. The solution which would have a pH closest to 7.
25. The solution which would have a pH between 4 and 7.
26. The solution which would have a pH between 7 and 10.
27. The solution which would form a blood red complex with potassium thiocyanate solution.

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28. The solubility of barium sulphate ($BaSO_4$) is $1.41x10^{-4}$ $moldm^{-3}$. The solubility product of this compound is

A 2.82×10^{-4}
B 1.19×10^{-2}
C 1.99×10^{-8}
D 7.05×10^{-5}
E 2.82×10^{-8}

Questions 29 and 30 require the following information:
The solubility product of PbI_2 is 7.9×10^{-9}.

29. The solubility of PbI_2 in water is, in $moldm^{-3}$,

A 1.25×10^{-3}
B 1.99×10^{-3}
C 8.89×10^{-5}
D 1.98×10^{-9}
E 3.95×10^{-9}

30. The solubility of PbI_2 in 0.10M NaI is, in $moldm^{-3}$,

A 7.9×10^{-11}
B 7.9×10^{-10}
C 7.9×10^{-9}
D 7.9×10^{-8}
E 7.9×10^{-7}

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31. In which compound does hydrogen carry an oxidation number of –1?

A NH_4Cl
B NaH
C H_2O_2
D $KHCO_3$
E HBr

32. Which is **NOT** a redox reaction?

A $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
B $Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$
C $CaCO_3 \rightarrow CaO + CO_2$
D $2NBr_3 + H_2O \rightarrow N_2 + 4Br^- + 2HOBr$
E $XeF_2 + 2Cl^- \rightarrow Xe + 2F^- + Cl_2$

33. Which is a disproportionation reaction?

A $SO_2 + H_2O \rightarrow H_2SO_3$
B $CH_4 + 2O_2 \rightarrow CO_2 + 2\ H_2O$
C $3\ NO_2 + H_2O \rightarrow 2\ HNO_3 + NO$
D $2\ KMnO_4 + 5\ SO_2 + 2\ H_2O \rightarrow 2\ MnSO_4 + K_2SO_4 + 2\ H_2SO_4$
E $S_2O_8^{2-} + 2\ I^- \rightarrow 2\ SO_4^{2-} + I_2$

34. Which set shows sulphur in order of **INCREASING** oxidation number?

A HS^-, H_2SO_4, SO_2.
B S, H_2S, SO_2
C H_2S, HSO_3^-, HSO_4^-.
D HSO_4^-, SO_3^{2-}, S.
E SO_3, SO_2, S

35. Which statement is **FALSE** for a voltaic cell?

A In the external circuit, the current consists of a flow of electrons.
B The electrolyte is often an aqueous solution.
C The current consists of a flow of ions through the electrolyte.
D Oxidation occurs at the positive electrode.
E A redox reaction takes place in the cell.

SECTION B: Answer **ALL** questions in the spaces provided in the question paper.

Use the following information where appropriate:

$R = 8.31\ J\ mol^{-1}\ K^{-1} = 0.082\ atm\ dm^3\ mol^{-1}\ K^{-1}$

1. The rate law for the reaction: $2P + Q \rightarrow 3R$ is
   $R = k\,[P]\,[Q]^2$ with a rate constant of $1.3 \times 10^{-3}\ M^{-2}\ s^{-1}$ at 298 K.

   a] Find the rate of the reaction the instant $30.0cm^3$ of 0.20 M P is mixed with $20.0cm^3$ of 0.25 M Q at 298 K. [2 marks]

   b] What is the value of the ***rate constant*** if the concentration of P is doubled and the concentration of Q is kept constant at 298 K? [1mark]

   c] The Arrenhius equation states that $k = Ae^{-Ea/RT}$.
   State two ways in which the value of k can be increased for any given process. [2 marks]

2. The equilibrium constant, K_p, for the dissociation of dinitrogen tetroxide to nitrogen dioxide is 0.14 at 298K. The reaction is: $N_2O_4\ (g) \rightleftharpoons 2NO_2(g)$.

   a] Find the equilibrium partial pressure of each gas when 0.015 mol of N_2O_4 is admitted into a 1.50 dm^3 vessel at 298 K and the system reaches equilibrium. [5 marks]

b] Find the total pressure of the system at equilibrium. [1 mark]

c] What effect, if any, will the addition of 0.01mol of an inert gas have on the equilibrium position if the volume is kept constant? **Show your reasoning.** [2 marks]

d] What effect, if any, will the addition of 0.01mol of an inert gas have on the equilibrium position if the total pressure is kept constant? **Show your reasoning.** [2 marks]

3. Use the following information wherever necessary.

$K_w = 1.0 \times 10^{-14}$
$K_a (NH_4^+) = 6.3 \times 10^{-10}$

Find the pH of

a] 0.20 M HCl [1 mark]

b] 0.20 M NaOH [1 mark]

c] 0.20 M NH_3 [3 marks]

d] a mixture of 20.0 cm^3 of 0.20 M HCl + 20.0 cm^3 of 0.20 M NaOH.
[1 mark]

f] a mixture of 30.0 cm^3 of 0.20 M HCl + 20.0 cm^3 of 0.20 M NaOH.
[2 marks]

g] a mixture of 20.0 cm^3 of 0.20 M HCl + 30.0 cm^3 of 0.20 M NaOH.
[2 marks]

h] a mixture of 20.0 cm^3 of 0.20 M HCl + 10.0 cm^3 of 0.20 M NH_3.
[2 marks]

i] a mixture of 20.0 cm^3 of 0.20 M HCl + 20.0 cm^3 of 0.20 M NH_3.
[3 marks]

j] a mixture of 20.0 cm^3 of 0.20 M HCl + 30.0 cm^3 of 0.20 M NH_3. [3 marks]

4. Use the following table of standard redox potentials wherever necessary.

	E^0/V
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(aq)$	-0.036
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.44

Hydrogen gas can be prepared by the reaction of hydrochloric acid on iron metal.

a] i] Write an ionic equation for the reaction. [1 mark]

ii] This reaction can be made to take place in a galvanic cell. Draw a fully labeled diagram of a **standard** galvanic cell in which this reaction takes place. Show the direction of flow of electrons and the polarity of the electrodes. [5 marks]

iii] What is the emf of the cell? [1 mark]

b] i] Find the standard cell potential for a cell in which the reaction: $Ag^{+}(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$ takes place. [1 mark]

ii] Given the Nernst Equation: $E = E^{0} - \frac{0.059}{n}\log Q$,

Find K_c for the process: $Ag^{+}(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$ [3 marks]

5. a] Acidified potassium dichromate($K_2Cr_2O_7$) oxidizes iron(II) to iron(III) in solution whilst it is being reduced to Cr^{3+}. Derive a balanced **ionic** equation for the reaction. [3 marks]

b] Alkaline potassium chlorate($KClO_3$) solution oxidizes hydrazine (N_2H_4) to nitrogen monoxide(NO) whilst being reduced to potassium chloride. Derive a balanced **ionic** equation for the reaction . [3 marks]

END OF EXAMINATION