Student Name ..... Student number .....Section .....

You may use the following information wherever necessary:

$R = 8.31\ J\ mol^{-1}\ K^{-1} = 0.0821\ atm\ dm^3\ mol^{-1}\ K^{-1} = 0.0821\ atm\ L\ mol^{-1}\ K^{-1}$
$K_p = K_c (0.0821T)^{\Delta n(gas)}$
$K_w = 1.0 \times 10^{-14}$ at 298 K

**SECTION A:** Multiple Choice . Answer **all** questions. [1 mark each = 30 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. 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

2. 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 $MgCO_3 \rightarrow MgO + CO_2$
D $I_2 + S_2O_3^{2-} \rightarrow 2\ I^- + S_4O_6^{2-}$
E $XeF_2 + 2\ Cl^- \rightarrow Xe + 2\ F^- + Cl_2$

3. Which is a disproportionation reaction?

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

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

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

5. 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 $\Delta[NO]$ is -0.006 mol $dm^{-3}$, then $\Delta[O_2]$, in mol $dm^{-3}$, is

A -5/4 x 0.006
B 5/4 x 0.006
C -4/5 x 0.006
D 4/5 x 0.006
E 4 x 5 x 0.006

6. The reaction: $2\ H_2\ (g) + 2\ NO\ (g) \rightarrow 2\ H_2O\ (g) + N_2\ (g)$ is first order in hydrogen and second order in nitrogen monoxide.
By what factor would the rate of the reaction change if the concentration of both reactants were doubled?

A 2
B 4
C 8
D 12
E 16

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

A increasing the temperature of the reaction mixture.
B increasing 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.

Student Name ..... Student number .....Section .....

8. The following data were obtained for the reaction:
$6\ I^-(aq) + BrO_3^-(aq) + 6\ H^+(aq) \rightarrow 3\ I_2(aq) + Br^-(aq) + 3\ H_2O(l)$

| Experiment | Initial $[I^-]$/M | Initial $[BrO_3^-]$/M | Initial $[H^+]$/M | Initial Rate of $I_2$ formation/$Ms^{-1}$ |
|---|---|---|---|---|
| 1 | 0.0020 | 0.0080 | 0.020 | $8.89 \times 10^{-5}$ |
| 2 | 0.0040 | 0.0080 | 0.020 | $1.78 \times 10^{-4}$ |
| 3 | 0.0020 | 0.0160 | 0.020 | $1.78 \times 10^{-4}$ |
| 4 | 0.0020 | 0.0080 | 0.040 | $3.56 \times 10^{-4}$ |

The rate law for the reaction is

A $R = k[I^-]^2[BrO_3^-]^2[H^+]$
B $R = k[I^-][BrO_3^-][H^+]$
C $R = k[I^-][BrO_3^-]^2[H^+]$
D $R = k[I^-]^2[BrO_3^-][H^+]$
E $R = k[I^-][BrO_3^-][H^+]^2$

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

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

A The overall reaction is $2\ NO_2(g) + F_2(g) \rightarrow 2\ NO_2F(g)$
B F is a reaction intermediate.
C Each elementary step is bimolecular.
D The energy of activation for step (i) is lower than that for step (ii).
E The rate law for the reaction is $R = k[NO_2][F_2]$

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

Step (i) $H_2O_2 + I^- \rightarrow H_2O + IO^-$

Step (ii) $H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^-$

The catalyst in this process is

A $H_2O_2$
B $O_2$
C $IO^-$
D $H_2O$
E $I^-$

11. Nitrogen and hydrogen combine reversibly to form ammonia according to the equation:
$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$.
0.20 mol each of $N_2$ and $H_2$ were introduced into a 1 $dm^3$ vessel at constant temperature.
When the system reached equilibrium, 0.10 mol of $NH_3$ was present.
Which set of values shows the concentration of each gas at equilibrium?

| | $[N_2]$/moldm$^{-3}$ | $[H_2]$/moldm$^{-3}$ | $[NH_3]$/moldm$^{-3}$ |
|---|---|---|---|
| A | 0.20 | 0.20 | 0.10 |
| B | 0.15 | 0.05 | 0.10 |
| C | 0.10 | 0.05 | 0.10 |
| D | 0.05 | 0.10 | 0.10 |
| E | 0.15 | 0.10 | 0.10 |

12. 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

Student Name ..... Student number .....Section .....

13. At 298K, $K_c$ for the process: $C(s) + O_2(g) \rightleftharpoons CO_2(g)$ is $1.2 \times 10^{96}$.
Which of the following **CANNOT** be deduced from the data?

A $K_c = \dfrac{[CO_2]}{[O_2]}$

B $K_p = K_c$.

C Equilibrium position lies far to the right.

D When carbon and oxygen react, the limiting reagent is almost completely used up.

E The rate of the reaction between carbon and oxygen to form carbon dioxide is extremely fast.

14. $K_p$ for the gas phase reaction: $Br_2 + 3\ F_2 \rightleftharpoons 2\ BrF_3$ is 5.29.
$K_p$ for the gas phase reaction: $BrF_3 \rightleftharpoons \frac{1}{2}\ Br_2 + 1\frac{1}{2}\ F_2$ is

A $\left(\dfrac{1}{5.29}\right)^{1/2}$

B $\left(\dfrac{1}{5.29}\right)^{2}$

C $(529)^{1/2}$

D $\left(\dfrac{1}{5.29}\right)^{2}$

E $(529)^{2}$

15. Consider the process $2\ SO_3(g) \rightleftharpoons 2\ SO_2(g) + O_2(g)$ $\Delta H = +198$ kJ.
The value of $K_c$ for this process can be increased by

A using a suitable catalyst.

B adding some $SO_3$ to an equilibrium mixture at constant volume.

C increasing the total volume of an equilibrium mixture.

D increasing the temperature.

E decreasing the temperature.

16. $K_p$ for the system : $NH_4CO_2NH_2(s) \rightleftharpoons 2\ NH_3(g) + CO_2(g)$ is $2.2 \times 10^{-4}$ at 298K. The partial pressure of carbon dioxide in an equilibrium mixture at 298 K is closest to

A 0.038 atm

B 0.076 atm

C 0.114 atm

D $7.3 \times 10^{-5}$ atm

E $1.05 \times 10^{-2}$ atm

17. Which change **CANNOT** upset equilibrium position of the system:
$NH_4CO_2NH_2(s) \rightleftharpoons 2\ NH_3(g) + CO_2(g)$ ?

A Increasing the mass of solid $NH_4CO_2NH_2$.

B Increasing the temperature.

C Decreasing the temperature.

D Increasing the volume of the containing vessel.

E Increasing the mass of $NH_3$ gas without changing the volume of the container.

18. 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 |

19. 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.

Student Name ..... Student number .....Section .....

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

A $H_2SO_4$/ $HSO_4^-$
B $NH_3$/ $NH_2^-$
C $NH_4^+$/ $NH_3$
D $H_3O^+$/ $OH^-$
E $HNO_3$/ $NO_3^-$

21. Which is **NOT** a strong acid?

A HCl
B $HClO_4$
C $HNO_3$
D $HNO_2$
E HI

22. Which set shows the substances in order of **INCREASING** acid strength?

A HBr, HCl, HF
B HF, $H_2O$, $NH_3$
C $HClO_4$, $HClO_3$, $HClO_2$
D $H_2SO_4$, $H_2SO_3$, $HSO_4^-$
E $HPO_4^{2-}$, $H_2PO_4^-$, $H_3PO_4$

23. The acidity constant for an acid, HA, is $3.5 \times 10^{-5}$. The $pK_b$ of its conjugate base is

A 4.5
B 9.5
C 14
D $1.0 \times 10^{-14}$
E $2.9 \times 10^{-10}$

24. 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 $FeCl_3$
D $FeCl_2$
E $BaCl_2$

25. 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 26 to 30** 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,

26. The solution which would have a pH closest to 4.
27. The solution which would have a pH closest to 7.
28. The solution which would have a pH closest to 10.
29. The solution which would have a pH between 4 and 7.
30. The solution which would have a pH between 7 and 10.

Student Name ..... Student number .....Section .....

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

You may use the following information wherever appropriate:

a) $R = 8.31\ J\ mol^{-1}\ K^{-1} = 0.0821\ atm\ dm^3\ mol^{-1}\ K^{-1} = 0.0821\ atm\ L\ mol^{-1}\ K^{-1}$

b) $k = Ae^{-Ea/RT}$

c) $$\ln\frac{k_2}{k_1} = \frac{E_a}{R} \times \frac{(T_2 - T_1)}{T_1 T_2}$$

d) $$\ln\frac{[A]_t}{[A]_0} = -kt$$

e) $$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

f) $K_p = K_c\,(0.0821T)^{\Delta n(gas)}$

g) $K_w = 1.0 \times 10^{-14}$ at 298 K

h) $K_a\,(NH_4^+) = 6.3 \times 10^{-10}$

i) $$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

**Remember to include units in your answers wherever appropriate.**

1. The reaction: $2\ ClO_2\,(aq) + 2\ OH^-\,(aq) \rightarrow ClO_3^-\,(aq) + ClO_2^-\,(aq) + H_2O\,(l)$ is first order in $OH^-$, and second order in $ClO_2$.

   a) Write a rate law for the reaction.

   [1]

   b) In an experiment carried out at a fixed temperature, the initial concentrations of $OH^-$, and $ClO_2$ were 0.015 mol $dm^{-3}$ and 0.010 mol $dm^{-3}$ respectively. It was found that the rate of hydroxide consumption was $3.00 \times 10^{-4}$ mol $dm^{-3}$ $s^{-1}$.

      i) Find the value of the rate constant, *k*, stating its correct units.

      [2]

      ii) What would be the value of the **rate constant** if the concentration of both reactants were doubled?

      [1]

      iii) What effect, if any, would doubling the concentration of the reactants have on the energy of activation for the process?

      [1]

      iv) What effect, if any, would increasing the temperature of the reaction mixture have on the energy of activation for the process?

      [1]

      v) What effect, if any, would increasing the temperature of the reaction mixture have on the value of the rate constant for the process?

      [1]

      vi) What effect, if any, would using a catalyst have on the energy of activation for the process?

      [1]

Student Name ..... Student number .....Section .....

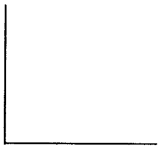
2. The decomposition of sulfuryl chloride($SO_2Cl_2$) to sulfur dioxide and chlorine is a first order process with a half life of 750 min.

a) What is the rate constant for the reaction? (Remember to state its units.)

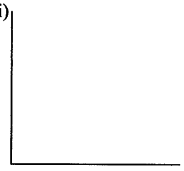
b) How long will it take for the concentration of a sample of sulfuryl chloride to be reduced by 35% ?

c) On the axes given, sketch graphs of
i) concentration of $SO_2Cl_2$ versus time.
ii) rate of decomposition of $SO_2Cl_2$ versus concentration of $SO_2Cl_2$
Be sure to label your axes. [3]

i)

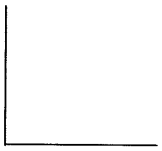


ii)

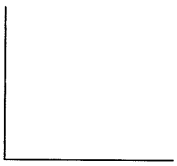


3. Hydrogen iodide (HI) undergoes zero order decomposition into hydrogen and iodine on a gold surface.
On the axes given, sketch graphs of
a) concentration of HI versus time.
b) reaction rate versus concentration of HI. [3]
Be sure to label your axes.

a)



b)



4. The activation energy for the reaction: $2\ N_2O\ (g) \rightarrow 2\ N_2\ (g) + O_2\ (g)$ is 200 kJ $mol^{-1}$.
How much faster would this reaction proceed at 230°C than at 200°C?
[3]

Student Name ..... Student number .....Section .....

5. The equilibrium constant, $K_p$, for the dissociation of dinitrogen tetroxide to nitrogen dioxide is 11 at 398K. The reaction is: $N_2O_4\,(g) \rightleftharpoons 2\,NO_2(g)$.

a) Find the equilibrium partial pressure of each gas when $N_2O_4$ at an initial pressure of 1.00 atm dissociates at 398 K.

[4]

c) Find the total pressure of the system at equilibrium.

[1 ]

d) Find the percent dissociation of dinitrogen tetroxide.

[1]

e) 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]

f) 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]

Student Name ..... Student number .....Section .....

6. Find the pH of

a) 0.020 M HCl

[1]

b) 0.020 M NaOH

[1]

c) 0.020 M $NH_3$

[3]

c) a mixture of 20.0 $cm^3$ of 0.020 M HCl + 20.0 $cm^3$ of 0.020 M NaOH.

[2]

f) a mixture of 30.0 $cm^3$ of 0.020 M HCl + 20.0 $cm^3$ of 0.020 M NaOH.

[2]

g) a mixture of 20.0 $cm^3$ of 0.020 M HCl + 30.0 $cm^3$ of 0.020 M NaOH.

[2]

h) a mixture of 20.0 $cm^3$ of 0.020 M HCl + 10.0 $cm^3$ of 0.020 M $NH_3$.

[2]

Student Name ..... Student number .....Section .....

i) a mixture of 20.0 $cm^3$ of 0.020 M HCl + 20.0 $cm^3$ of 0.020 M $NH_3$. [3]

j) a mixture of 20.0 $cm^3$ of 0.020 M HCl + 30.0 $cm^3$ of 0.020 M $NH_3$. [3]

7. 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 |
| $Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$ | -0.036 |
| $Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$ | -0.44 |

a) This reaction: $Ag^+(aq) + Fe^{2+}(aq) \rightarrow Ag(s) + Fe^{3+}(aq)$ can be made to take place in a galvanic cell.

i) 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]

iii) What is the emf of the cell?

[1]

Student Name ..... Student number .....Section .....

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

find the emf of the cell: Fe (s) | $Fe^{2+}$ (0.001 M) || $Ag^+$ (0.10 M) | Ag (s)

[3]

8. 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]

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

[3]

**END OF EXAMINATION**