SECTION A: MULTIPLE CHOICE. For each question, select the most appropriate answer, and shade the letter corresponding to this answer on the answer sheet provided.

1. Consider the gas phase reaction: a A + b B $\rightarrow$ c C + d D + e E.
The rate law is: Rate = $k[A]^q [B]^r$.
Which statement is **false**?
   A The exponents, q and r, are often integers.
   B The exponents, q and r, are always equal to the coefficients a and b respectively.
   C The exponents, q and r, must be determined experimentally.
   D The overall reaction order is q + r.
   E The symbol, k, represents the rate constant.

2. For the reaction: 6 CH_2O + 4 NH_3 $\rightarrow$ $(CH_2)_6N_4$ + 6 H_2O
the rate is expressed as $-\frac{1}{6}\frac{\Delta[CH_2O]}{\Delta t}$. An equivalent expression is
   A $-\frac{1}{4}\frac{\Delta[NH_3]}{\Delta t}$
   B $+\frac{1}{4}\frac{\Delta[NH_3]}{\Delta t}$
   C $-\frac{6}{4}\frac{\Delta[NH_3]}{\Delta t}$
   D $+\frac{6}{4}\frac{\Delta[NH_3]}{\Delta t}$
   E $-\frac{4}{6}\frac{\Delta[NH_3]}{\Delta t}$

3. For the decomposition of nitrosyl chloride, $\Delta H = +38$ kJ mol^{-1}.
NOCl (g) $\rightarrow$ NO (g) + ½ Cl_2 (g)
The activation energy for this reaction is 100 kJ mol^{-1}. The activation energy for the reverse reaction is
   A 38 kJ
   B 62 kJ
   C 76 kJ
   D 100 kJ
   E 138 kJ

4. Most reactions are more rapid at higher temperatures than at lower temperatures. This is consistent with
   1. an increase in the rate constant with increasing temperature.
   2. an increase in the activation energy with increasing temperature.
   3. an increase in the percentage of "high energy" collisions with increasing temperature.

   Which of the given choices is/are correct?
   A 1 only.
   B 2 only.
   C 3 only.
   D 1 and 3.
   E 1, 2 and 3.

5. For the **elementary** reaction: $2\ P + Q \rightarrow R + S$
the rate law must be
A $R = k[P]^2[Q]$
B $R = k[P][Q]^2$
C $R = k[P][Q]$
D $R = k[P]^2$
E determined by experiment.

6. The gas phase decomposition of N_2O_5 is a first order process. The decomposition reaction is:
$N_2O_5 \rightarrow 2\ NO_2 + \frac{1}{2}\ O_2$.

10.0 g of N_2O_5 are placed in vessel 1 and 5.0 g N_2O_5 in vessel 2. The vessels are at the same temperature and pressure.

How much time is required for half of the N_2O_5 decompose in each vessel?

A Vessel 1 requires twice as much time as vessel 2.
B Vessel 2 requires twice as much time as vessel 1.
C Vessel 1 requires four times as much time as vessel 2
D Vessel 2 requires four times as much time as vessel 1.
E Vessel 1 requires as much time as vessel 2.

7. The equilibrium constant for the reaction $A + 2\ B \rightleftharpoons C + 5/2\ D$ is 4.0.
What is the value of the equilibrium constant for the reaction
$2\ C + 5\ D \rightleftharpoons 2\ A + 4\ B$ at the same temperature?
A 0.25
B 16
C 2.0
D 8.0
E 0.063

Questions 8 and 9.
At a given temperature, 0.012 mol NO, 0.008 mol Cl_2, and 0.020 mol NOCl were placed in a 1.0 dm^3 container. The following equilibrium was established:
$2\ NOCl\ (g) \rightleftharpoons 2\ NO\ (g) + Cl_2\ (g)$. At equilibrium 0.024 mol NOCl was present.

8. How many moles of Cl_2 were present at equilibrium?
A 0.002
B 0.004
C 0.006
D 0.008
E 0.010

9. What is the value of the equilibrium constant, K_c?
A 4.45×10^{-4}
B 6.67×10^{-4}
C 0.111
D 0.167
E 1500

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10. In a reversible chemical reaction at constant temperature, the addition of a catalyst
A increases the value of the equilibrium constant.
B increases the kinetic energy of the reacting molecules.
C decreases the enthalpy change for the forward process.
D increases the concentration of the products at equilibrium.
E has no effect on equilibrium position.

11. Solid HgO, liquid Hg, and gaseous O_2 are placed in a glass bulb and allowed to reach equilibrium at a constant temperature.
$2\ HgO\ (s) \rightleftharpoons Hg\ (l) + O_2\ (g)$. $\Delta H = +43.3$ kcal.
The mass of Hg in the bulb can be increased by

A adding some HgO.
B adding some O_2.
C reducing the volume of the bulb.
D lowering the temperature.
E removing some O_2.

12. Dinitrogen tetroxide dissociates to nitrogen dioxide:
$N_2O_4\ (g) \rightleftharpoons 2\ NO_2\ (g)$.
At 25^0C, 0.11 mol N_2O_4 reacts to form 0.10 mol N_2O_4 and 0.02 mol NO_2 at equilibrium. At 90^0C, 0.11 mol N_2O_4 reacts to form 0.50 mol N_2O_4 and 0.12 mol NO_2 at equilibrium.
From this data, it can be concluded that

A N_2O_4 molecules react by a second order rate law.
B N_2O_4 molecules react by a first order rate law.
C the reaction is endothermic.
D the equilibrium constant for the reaction decreases with an increase in temperature.
E N_2O_4 molecules react faster at 25^0C than at 90^0C.

13. Which set does **not** constitute an acid/base conjugate pair?

A $HCOOH/HCOO^-$
B H_2O/OH^-
C H_3O^+/H_2O
D H_3PO_4/HPO_4^{2-}
E HCl/Cl^-

14. The pH of 0.002 M KOH is closest to

A 11.3
B 2.7
C 2
D 12
E 14

15. Which of the following is the weakest acid?

A $HClO_4$
B $HClO_3$
C $HClO_2$
D HClO
E HCl

Questions 16 and 17 concern the following salts.

A NH_4Cl
B K_2CO_3
C $FeCl_3$
D $Fe(NO_3)_2$
E NaCl

16. Which salt, when added to water, will **not** change the pH?

17. Which salt, when added to water, will increase the pH?

18. A 1.0 M aqueous solution of a weak acid, HX, has a pH of 4. What is the percent dissociation of HX in the solution?

A 10 %
B 1.0 %
C 0.10 %
D 0.01 %
E 0.001

19. A 7.2×10^{-3} M solution of ethanoic acid is 5 % dissociated. In a 7.2×10^{-4} M solution, the percent dissociation would be

A 5 %
B < 5 %
C > 5 %
D 100 %
E 0 %

20. A 7.2×10^{-3} M solution of ethanoic acid is 5 % dissociated. What is the pH of the solution?

A 5.0
B 2.1
C 3.4
D 0.0036
E 7.0

21. Which statement is true of the titration of a weak monoprotic acid with the strong base, sodium hydroxide?

A At the equivalence point, the pH is 7.
B At the equivalence point the solution is acidic.
C At the equivalence point the number of moles of acid is greater than the number of moles of the base.
D At the equivalence point the number of moles of the base is greater than the number of moles of the acid.
E At the equivalence point the number of moles of acid is equal to the number of moles of the base.

22. To 1.0 dm^3 of water, 2.0×10^{-6} mol $Pb(NO_3)_2$, 6.0×10^{-6} mol K_2CrO_4 and 1.0 mol NaCl are added. Which precipitate will form?
$K_{sp}(PbCrO_4) = 1.0 \times 10^{-16}$; $K_{sp}(PbCl_2) = 2.0 \times 10^{-5}$

A $PbCl_2$
B $PbCrO_4$
C Both $PbCl_2$ and $PbCrO_4$
D KCl
E Na_2CrO_4

Questions 23 - 25 concern the reactions:

A $Cl_2 + H_2O \rightarrow HCl + HOCl$
B $2\ Na + H_2O \rightarrow 2\ NaOH + H_2$
C $CaO + SiO_2 \rightarrow CaSiO_3$
D $NH_4NO_3 \rightarrow N_2O + 2\ H_2O$
E $H_2 + Cl_2 \rightarrow 2\ HCl$

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

24. Which is a disproportionation reaction?

25. In which reaction is the oxidation number of hydrogen reduced?

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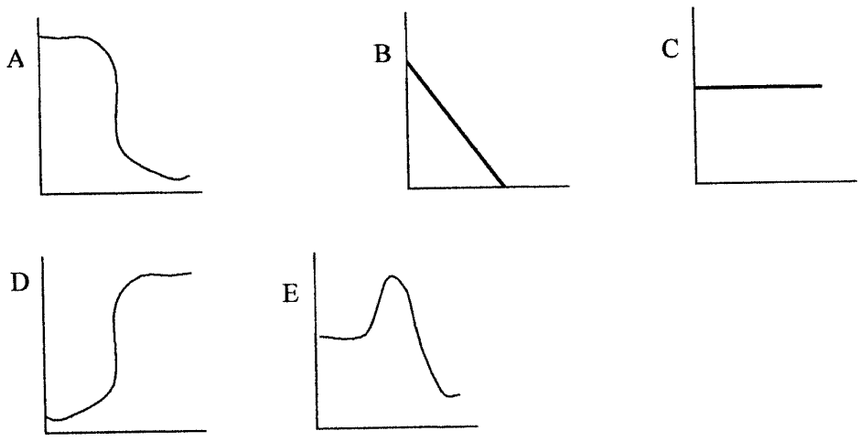
26. A voltaic cell consists of a copper electrode immersed in a solution of 1.0 M copper(II)chloride and a zinc electrode immersed in a solution of 1.0 M zinc nitrate. The two half cells are connected by means of a salt bridge.
Given the standard electrode potential (E^0) values:
Cu^{2+}/Cu +0.34V
Zn^{2+}/Zn -0.76V

Which statement is **false**?

A The copper electrode is the cathode.
B The mass of the zinc electrode decreases during discharge.
C The concentration of Cu^{2+} decreases during discharge.
D The cell potential is zero when the concentration of Cu^{2+} is equal to the concentration of Zn^{2+}.
E Electrons flow through the external circuit from the zinc electrode to the copper electrode.

Questions 27 –30 concern the graphs A to E. Each graph may be used once, more than once, or not at all.



Which graph best represents

27. rate versus concentration of X, for a reaction which is zero order in X.

28. energy of activation versus temperature for a reaction.

29. the titration curve for the titration of an acid with a base.

30. the titration curve for the titration of a base with an acid.

Section B: Answer **all** questions in this section in the spaces provided in the question paper.

1. Phosgene ($COCl_2$) is an important intermediate in the manufacture of certain plastics. It is produced by the reaction: $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$ for which the equilibrium constant, K_p, is 0.20 at 600 ^{0}C.
   0.10 mol each of CO and Cl_2 are placed in a 1.0 dm^3 vessel and allowed to reach equilibrium.
   a] Find the partial pressure of each gas at equilibrium. [5 marks]

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

2. Write expressions for K_a for a weak acid HA, K_b for its conjugate base, and K_w. Use these to show that $K_w = K_a \times K_b$ for an acid/base conjugate pair. [2 marks]

3. Find the pH of the following mixtures.
$K_a(CH_3COOH) = 1.8 \times 10^{-5}$.

a] $30.0\ cm^3$ 0.020 M HCl + $20.0\ cm^3$ 0.030 M KOH. [2 marks]

b] $20.0\ cm^3$ 0.20 M CH_3COOH + $20.0\ cm^3$ 0.20 M KOH. [5 marks]

4. A buffer solution, A, is 1.0 M in CH_3COOH and 1.0 M in CH_3COONa.
Another buffer solution, B, is 0.10 M in CH_3COOH and 0.10 M in CH_3COONa.

a] Show that both A and B have the same pH. [3 marks]

b] Show that A has better buffering capacity than B by finding the pH of each solution after 1.0 cm^3 of 1.0 M HCl has been added to each solution separately.
(Ignore the small change in volume on addition of the HCl). [5 marks]

5. A saturated solution of H_2S is 0.10 M. The equilibrium constant for the reaction :
$H_2S\,(aq) + H_2O\,(l) \rightleftharpoons 2\,H_3O^+\,(aq) + S^{2-}(aq)$ is 1.1×10^{-20}.

a] An aqueous solution buffered at pH 3.00 is saturated with H_2S. What is the concentration of S^{2-} in this solution? [2 marks]

b] A solution which is 0.0010 M in Fe^{2+}, Cd^{2+}, Co^{2+}, and Mn^{2+} is saturated with H_2S at a pH of 3.00. Which metals form a sulphide precipitate? Show your reasoning. [2 marks]

K_s values are:

Sulphide	K_s
FeS	6×10^{-18}
CdS	8×10^{-27}
CoS	4×10^{-21}
MnS	2.5×10^{-10}

6. Derive a balanced ionic equation for each reaction by writing half equations then combining them.

a] In acid medium:

$S_2O_6^{2-}$ (aq) + $HClO_2$ (aq) → SO_4^{2-} (aq) + Cl_2 (g) [3 marks]

b] In basic medium:

Ag (s) + HS^- (aq) + CrO_4^{2-} (aq) → Ag_2S (s) + $Cr(OH)_3$ (s) [3 marks]

7. A **standard** voltaic cell is made by placing a magnesium electrode immersed in a solution of magnesium chloride in one compartment and a platinum electrode in contact with hydrochloric acid and hydrogen gas in the other compartment. E^0 for the Mg^{2+}/Mg couple is –2.38 V.

a] What is the concentration of magnesium chloride? [1 mark]

b] What is the pressure of the hydrogen gas? [1 mark]

c] Draw a **fully labeled** diagram of the cell, including the anode and the cathode, and indicate the direction of flow of electrons. [5 marks]

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

ii) Given the Nernst equation: $E = E^0 - \frac{0.059}{n} \log Q$, find the value of the equilibrium constant for the reaction:
$Mg\ (s) + 2H^+ \rightleftharpoons Mg^{2+}\ (aq) + H_2\ (g)$ [4 marks].

END OF EXAMINATION