Name ____

IB12 midterm review packet

Units: rates equilibrium spectroscopy acids and bases electrochemistry

For these five units the topics are listed, and sample questions included.

Hand this midterm review packet in on the day of the midterm for up to 100 points that will be added to Q2

Scoring:

20% for effort during review

30% for neatness

25% for correct detailed answers

25% for completing this packet

Important note: include a complete sentence explanation for each multiple choice answer.

Unit 1: rates of reaction

Topics:

Collision theory	Activation energy	Reaction order
Rate measurement	Arrhenius equation	The rate constant
Relative rates of reaction	Factors that affect rate	Rate order and graphs
Boltzmann distribution	Rate law	Reaction mechanisms
Energy diagrams	Catalysts	

Sample questions

1. Consider the following reaction.

$$2P + Q \rightarrow R + S$$

This reaction occurs according to the following mechanism.

$$P + Q \rightarrow X \quad \textit{slow}$$
$$P + X \rightarrow R + S \quad \textit{fast}$$

What is the rate expression?

A. rate = $k[P]$
C. rate = $k[P][Q]$
B. rate = $k[P][X]$
D. rate = $k[P]^2[Q]$

note: for this midterm review packet include a complete sentence explanation for each multiple choice question

2. What happens when the temperature of a reaction increases?

A. The activation energy increases.
C. The enthalpy change increases.
B. The rate constant increases.
D. The order of the reaction increases.

3. This question refers to the following reaction.

$$X_2 + 2Y \rightarrow 2XY$$

The reaction occurs in a series of steps.

$$X_2 \rightarrow 2X \quad \textit{slow}$$
$$X + Y \rightarrow XY \quad \textit{fast}$$

What is the rate-determining step for this reaction mechanism?

A. $X_2 + 2Y \rightarrow 2Y$

B. $X_2 \rightarrow 2X$

C. $X_2 + Y \rightarrow XY + X$

D. $X + Y \rightarrow XY$

4. This question refers to the following reaction.

$$X_2 + 2Y \rightarrow 2XY$$

The reaction occurs in a series of steps.

$$X_2 \rightarrow 2X \quad \textit{slow}$$
$$X + Y \rightarrow XY \quad \textit{fast}$$

What is the rate expression for this reaction?

A. rate = $k[XY]$

B. rate = $k[X_2][Y]^2$

C. rate = $k[X_2]$

D. rate = $k[2X]$

5. Consider the following reaction.

$$5Br^-(aq) + BrO_3^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$$

The rate expression for the reaction is found to be:

$$\text{rate} = k[Br^-]\,[BrO_3^-][H^+]^2$$

Which statement is correct?

A. The overall order is 12.

B. Doubling the concentration of all of the reactants at the same time would increase the rate of the reaction by a factor of 16.

C. The units of the rate constant, k, are mol $dm^{-3}\,s^{-1}$.

D. A change in concentration of Br^- or BrO_3^- does not affect the rate of the reaction.

6. The rate expression for a reaction is:

$$\text{rate} = k\,[X][Y]$$

Which statement is correct?

A. As the temperature increases the rate constant decreases.

B. The rate constant increases with increased temperature but eventually reaches a constant value.

C. As the temperature increases the rate constant increases.

7. Two species, P and Q, react together according to the following equation.

$$P + Q \rightarrow R$$

The accepted mechanism for this reaction is

$$P + P \rightleftharpoons P_2 \quad \textit{fast}$$
$$P_2 + Q \rightarrow R + P \quad \textit{slow}$$

What is the order with respect to P and Q?

	P	Q
A.	1	1
B.	1	2
C.	2	1
D.	2	2

8. The activation energy of a reaction may be determined by studying the effect of a particular variable on the reaction rate. Which variable must be changed?

A. pH

B. Concentration

C. Surface area

D. Temperature

9. On the axes below sketch two Maxwell-Boltzmann energy distribution curves for the same sample of gas, one at a temperature T and another at a higher temperature T'. Label both axes. Explain why raising the temperature increases the rate of a chemical reaction.

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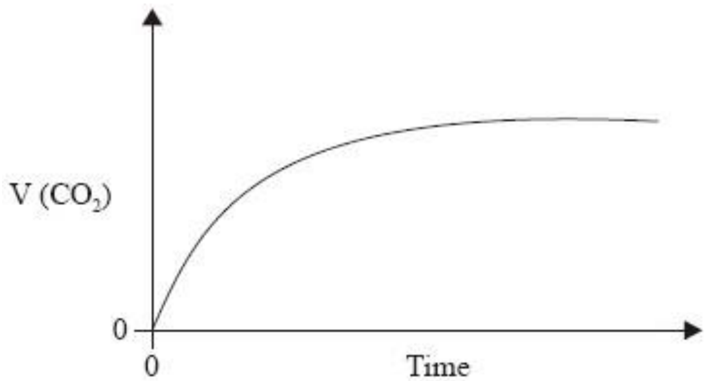
10. The graph below shows how the volume of carbon dioxide formed varies with time when a hydrochloric acid solution is added to excess calcium carbonate in a flask.



A. Explain the shape of the curve.

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B. The experiment is repeated using a sample of hydrochloric acid with double the volume, but half the concentration of the original acid. Draw a second line on the graph to represent this change. Explain why the shape of the curve is different.

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11. Given the following enthalpy changes:

A+B → C ΔH = -35 kJ/mol

A+D → E+F ΔH = 20 kJ/mol

F → C + E ΔH = 15 kJ/mol

What is the ΔH for the reaction 2A + B + D → 2F?

A. 70 kJ/mol

B. -40 kJ/mol

C. 0 kJ/mol

D. -70 kJ/mol

E. -30 kJ/mol

12. Consider the decomposition of NO2.

2NO2(g) → 2NO(g) + O2(g).

At 650K, the rate constant is 1.66 sec-1. At 700K, the constant is 7.39 sec-1. Calculate the activation energy.

13. Analysis of a compound containing only H, N, O, and C reveals that the compound contains 0.320% hydrogen, 27.0% nitrogen, 23.04% oxygen, and 49.64% carbon. This hypothetical compound has a molecular weight of 1252.754 g/mol. Determine its molecular formula. Show your work clearly and circle your answer for credit.

Unit 2: equilibrium

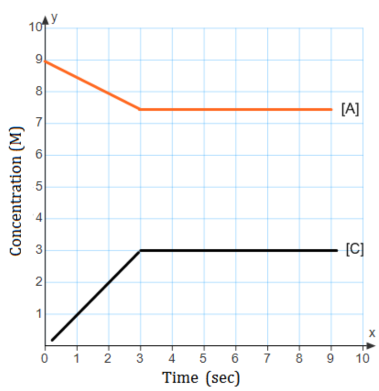
Topics:

- Physical and chemical equilibrium
- The equilibrium constants
- Le Chateliers principle
- Equilibrium law

1. A chemical reaction is observed to have a forward rate of 2.1 M/sec, and a reverse rate of 2.1 M/sec. Therefore at that point in time

(A) all chemical reactions have ceased
(B) the reaction is in a state of chemical equilibrium
(C) the rate constants of the forward and reverse reactions are both 1
(D) the value of the equilibrium constant is 1
(E) the yield for the chemical reaction is 50%
(F) All of the above

2. The progress of the reaction of A (g) $\rightleftharpoons$ 2C (g) + D(s) was measured and is shown below:



What would be the value of the equilibrium constant for the reaction above?

(A) 1.2
(B) 3.6
(C) 0.833

(D) 1.8
(E) 3.0

3. Which of the following expressions is the correct equilibrium-constant expression for the reaction below?

$$(NH_4)_2Se\ (s) \rightleftharpoons 2NH_3\ (g) + H_2Se\ (g)$$

(A) $[NH_3][H_2Se]/(NH_4)_2Se$
(B) $(NH_4)_2Se/[NH_3]^2[H_2Se]$
(C) $1/[(NH_4)_2Se]$
(D) $[NH_3]^2[H_2Se]$
(E) $[NH_3]^2[H_2Se]/[(NH_4)_2Se]$
(F) $[NH_3]^2[H_2Se]/0$

4. The equilibrium constant for the gas phase reaction
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
is $K_{eq} = 4.34 \times 10^{-3}$ at 300 °C. At equilibrium, __________.

(A) products predominate
(B) reactants predominate
(C) roughly equal amounts of products and reactants are present
(D) only products are present
(E) only reactants are present

5. Consider the following equilibrium:
$2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g)$
The equilibrium cannot be established when __________ is/are placed in a 1.0-L container.

(A) 0.25 mol $SO_2(g)$ and 0.25 mol $O_2(g)$
(B) 0.75 mol $SO_2(g)$
(C) 0.25 mol $SO_2(g)$ and 0.25 mol $SO_3(g)$
(D) 0.50 mol $O_2(g)$ and 0.50 mol $SO_3(g)$
(E) 1.0 mol $SO_3(g)$

6. The equilibrium constant (K_p) at 721 K for the reaction $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ is 0.0198. At equilibrium, the partial pressures of H_2 and I_2 are 0.710 and 0.888 atm, respectively. The partial pressure of HI is __________ atm.

(A) 7.87
(B) 1.98
(C) 5.64
(D) 0.125
(E) 0.389

7. A reaction vessel is charged with hydrogen iodide, which partially decomposes to molecular hydrogen and iodine:

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g).$$

When the system comes to equilibrium at 425 °C, P_{HI} = 0.808atm, and $P(H_2) = P(I_2)$ = 0.0860atm. The value of K_p at this temperature is __________.

(A) 9.15×10^{-3}
(B) 1.30×10^{-2}
(C) K_p cannot be calculated for this gas reaction when the volume of the reaction vessel is not given.
(D) 54.3
(E) 1.13×10^{-2}

8. At high temperatures, molecular hydrogen and molecular bromine react to partially form hydrogen bromide:

$$H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$$

A mixture of 0.682 mol of H_2 and 0.440 mol of Br_2 is combined in a reaction vessel with a volume of 2.00 L. At equilibrium at 700 K, there are 0.566 mol of H_2 present. At equilibrium, there are __________ mol of Br_2 present in the reaction vessel.

(A) 0.200
(B) 0.480
(C) 0.500
(D) 0.400
(E) 0.324

9. Two moles of gas A are placed in a one liter vessel and decompose into the gaseous products B and C according to the equation

$2A(g) \rightleftharpoons B(g) + C(g)$.

If it is 40.0% dissociated at equilibrium, what is the value of the equilibrium constant?

(A) .025
(B) .011
(C) .012
(D) .111

10. At 22 °C, K_p = 0.070 for the equilibrium: $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$
A sample of solid NH_4HS is placed in a closed vessel and allowed to equilibrate. Calculate the equilibrium partial pressure (atm) of ammonia, assuming that some solid NH_4HS remains.

(A) 0.26
(B) 0.070
(C) 0.52
(D) 4.9×10^{-3}
(E) 3.8

11. At 100°C the reaction below has an equilibrium constant, K_{eq}, value of 2.2×10^{-10}. If 1.00 mol of phosgene, $COCl_2$, is placed in a 10.0 L flask, calculate the concentration of carbon monoxide at equilibrium.

$COCl_{2(g)} \rightleftharpoons CO_{(g)} + Cl_{2(g)}$

(A) 0.075
(B) 4.7×10^{-5}
(C) 0.52
(D) 4.7×10^{-6}
(E) 0.154

12. For which one of the following is the value of K_p smaller than that of K_c at 25øC?

(A) $H_2(g) + F_2(g) \rightleftharpoons 2HF(g)$
(B) $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$
(C) $Al_2(SO_3)_3(s) + 6HCl(g) \rightleftharpoons 2AlCl_3(s) + 3H_2O(l) + 3SO_2(g)$
(D) $NH_4Br(s) + KOH(s) \rightleftharpoons NH_3(g) + KBr(s) + H_2O(l)$
(E) $2HF(g) \rightleftharpoons H_2(g) + F_2(g)$

13. For which one of the following does $K_c = K_p$ at 25°C?

(A) $H_2(g) + F_2(g)\ ) \rightleftharpoons 2HF(g)$
(B) $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$
(C) $Al_2(SO_3)_3(s) + 6HCl(g) \rightleftharpoons 2AlCl_3(s) + 3H_2O(l) + 3SO_2(g)$
(D) NH4Br(s) + KOH(s) ⇌ NH3(g) + KBr(s) + H2O(l)
(E) $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$

14. Given the following reaction at equilibrium, if $K_c = 6.44 \times 10^5$ at 230.0 °C, K_p = __________.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

(A) 3.67×10^{-2}
(B) 1.56×10^4
(C) 6.44×10^5
(D) 2.66×10^6
(E) 2.67×10^7

15. For the reaction,

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$$

at 450.0 K the equilibrium constant, K_c, has a value of 4.62. A system was charged to give these initial concentrations, $[SO_3]$ = 0.254 M, $[O_2]$ = 0.00855 M, $[SO_2]$ = 0.500 M. In which direction will it go?

(A) to the right or the left depending on the pressure
(B) to the left
(C) it will remain at the same concentrations
(D) to the right
(E) to the right or the left depending on the volume

16. Consider the following reaction at equilibrium:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H° = -99\ kJ$$

Le Chatelier's principle predicts that an increase in temperature will result in _______.

(A) a decrease in the partial pressure of SO_3
(B) a decrease in the partial pressure of SO_2
(C) an increase in K_{eq}
(D) no changes in equilibrium partial pressures
(E) the partial pressure of O_2 will decrease

17. Of the following equilibria, only __________ will shift to the left in response to a decrease in volume.

(A) $H_2 (g) + Cl_2 (g) \rightleftharpoons 2HCl (g)$
(B) $2SO_3 (g) \leftrightarrows 2SO_2 (g) + O_2 (g)$
(C) $N_2 (g) + 3H_2 (g) \rightleftharpoons 2NH_3 (g)$
(D) $4Fe (s) + 3O_2 (g) \rightleftharpoons 2Fe_2O_3 (s)$
(E) $2HI (g) \rightleftharpoons H_2 (g) + I_2 (g)$

18. In which of the following reactions would increasing pressure at constant temperature not change the concentrations of reactants and products, based on Le Chatelier's principle?

(A) $N_2 (g) + 3H_2 (g) \rightleftharpoons 2NH_3 (g)$
(B) $N_2O_4 (g) \rightleftharpoons 2NO_2 (g)$
(C) $N_2 (g) + 2O_2(g) \rightleftharpoons 2NO_2 (g)$
(D) $2N_2 (g) + O_2 (g) \rightleftharpoons 2N_2O (g)$
(E) $N_2 (g) + O_2 (g) \rightleftharpoons 2NO (g)$

19. The reaction below is exothermic:

$$2SO_2 (g) + O_2 (g) \rightleftharpoons 2SO_3 (g)$$

Le Chatelier's Principle predicts that __________ will result in an increase in the number of moles of SO_3 in the reaction container.

(A) increasing the pressure
(B) decreasing the pressure
(C) increasing the temperature
(D) removing some oxygen
(E) increasing the volume of the container
(F) all of the above

20. Consider the following system, which is at equilibrium,

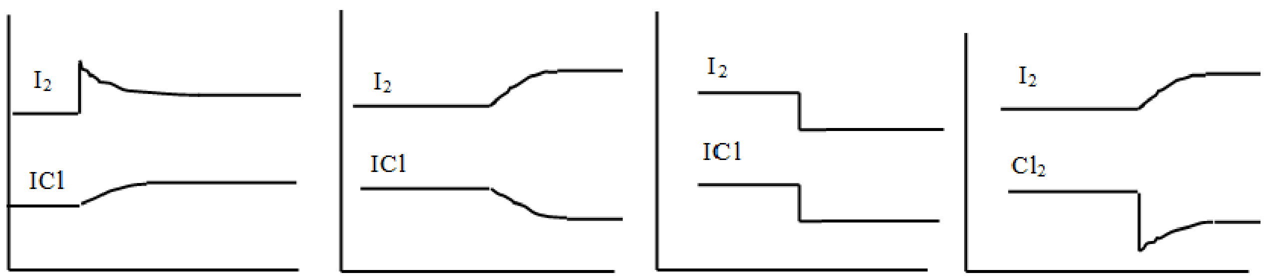
$$3C (s) + 3H_2 (g) \rightleftharpoons CH_4 (g) + C_2H_2 (g)$$

The result of removing some $C(s)$ from the system will be:

(A) K_c increases
(B) more $C(s)$ is produced
(C) no further change occurs
(D) more $CH_4(g)$ and $C_2H_2(g)$ are produced to restore the equilibrium
(E) more $C_2H_2(g)$ is consumed to restore the equilibrium

21. Consider the following graphs showing concentration vs reaction progress for the reaction:

$I_{2(g)}$ + $Cl_{2(g)}$ ⇄ 2 $ICl_{(g)}$ + heat



(A) (B) (C)

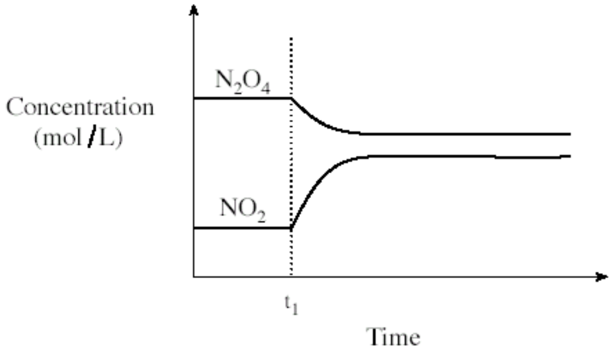
(D)

Which graph shows the predicted effect of increasing the temperature?

A) A
B) B
C) C
D) D

22. Consider the following equilibrium reaction:

$N_2O_{4(g)}$ ⇆ $2NO_{2(g)}$



At time t_1, heat is applied to the system. Which of the following best describes the equilibrium reaction and the change in K*eq*?

(A) exothermic and K*eq* increases
(B) exothermic and K*eq* decreases
(C) endothermic and K*eq* increases
(D) endothermic and K*eq* decreases

23. The K_{eq} for the equilibrium below is 0.135 at 700.0 ° C.
$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$.
What is the value of K_{eq} at this temperature for the following reaction?
$SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$

(A) 0.224
(B) 0.0185
(C) 0.112
(D) 7.40
(E) -0.112

24. Given the two reactions shown with their equilibrium constants,

$PCl_3(g) + \frac{1}{2}O_2(g) \leftrightarrows POCl_3(g)$ K_1
$NO(g) + \frac{1}{2}O_2(g) \leftrightarrows NO_2(g)$ K_2

What is the equilibrium constant for the reaction,

$PCl_3(g) + NO_2(g) \leftrightarrows POCl_3(g) + NO(g)$

(A) K_1K_2
(B) K_2/K_1
(C) K_1/K_2
(D) $(K_1K_2)^{-1}$
(E) K_2-K_1

25. Using this data,

$2\ NO\ (g)\ +\ Cl_2\ (g) \leftrightarrows 2\ NOCl\ (g)$ $K_c = 3.20 \times 10^{-3}$

$2\ NO_2\ (g) \leftrightarrows 2\ NO\ (g)\ +\ O_2\ (g)$ $K_c = 15.5$

calculate a value for K_c for the reaction,

$NOCl\ (g)\ +\ \frac{1}{2}\ O_2\ (g) \leftrightarrows NO_2\ (g)\ +\ \frac{1}{2}\ Cl_2\ (g)$

(A) 2.06×10^{-4}
(B) 4.84×10^{-3}
(C) 0.223
(D) 4.49
(E) 20.2

26. $CuO\ (s) + H_2\ (g) \leftrightarrows Cu\ (s) + H_2O\ (g)$; $\Delta H = -\ 2.0$ kilojoules

When the substances in the equation above are at equilibrium at pressure P and temperature T, the equilibrium can be shifted to favor the products by

(A) increasing the pressure by means of a moving piston at constant T
(B) increasing the pressure by adding an inert gas such as nitrogen
(C) decreasing the temperature
(D) allowing some gases to escape at constant P and T
(E) adding a catalyst

27. $4\ HCl\ (g) + O_2\ (g) \leftrightarrows 2\ Cl_2\ (g) + 2\ H_2O\ (g)$

Equal numbers of moles of HCl and O_2 in a closed system are allowed to reach equilibrium as represented by the equation above. Which of the following must be true at equilibrium?

I. [HCl] must be less than $[Cl_2]$.
II. $[O_2]$ must be greater than [HCl].
III. $[Cl_2]$ must equal $[H_2O]$.

(A) I only
(B) II only
(C) I and III only
(D) II and III only
(E) I, II, and III

28. For the equilibrium system: $CO\ (g) + 2\ H_2\ (g) \leftrightarrows CH_3OH\ (l)$, what is Keq ?

(A) Keq = $[CH_3OH]/2[CO]\ [H_2]$
(B) Keq = $[CH_3OH]/[CO]\ [H_2]^2$
(C) Keq = $1/\ 2[CO][H_2]$
(D) Keq = $1/\ [CO][H_2]^2$

29. $H_2\ (g) + I_2\ (g) \leftrightarrows 2HI\ (g)\quad \Delta H > 0$

Which of the following changes to the equilibrium system represented above will increase the quantity of HI(g) in the equilibrium mixture/

I. adding $H_2(g)$
II. increasing the temperature
III. decreasing the pressure

(A) I only
(B) III only
(C) and II only
(D) II and III only
(E) I, II and III

30. At 1500 K the equilibrium constant K = 1.0×10^{-5} for

$N_2\ (g) + O_2\ (g) \leftrightarrows 2NO\ (g)$

If the initial concentration N_2 is 0.80M and O_2 is 0.20M, what is the concentration of nitrogen monoxide (NO) in moles per liter when the system reaches equilibrium?

a. 1.0×10^{-5}
b. 1.3×10^{-3}
c. 2.6×10^{-4}
d. 1.7×10^{-2}
e. 5.3×10^{3}

Insert spectroscopy unit here

Unit 3: acids and bases
Topics:
Sample questions
Reminder: for multiple choice include a complete sentence explanation for each question

Name:____

IB acids and bases test

1. What is an acid? What is a base?

(Total 1 mark)

2. The K_b value for a base is 5.0×10^{-2} mol dm^{-3} at 298 K. What is the K_a value for its conjugate acid at this temperature?

Ka x kb = 10-14

A. 5.0×10^{-2}
B. 2.0×10^{-6}
C. 2.0×10^{-12}
D. 2.0×10^{-13}

Note: include a complete sentence explanation for each multiple choice answer

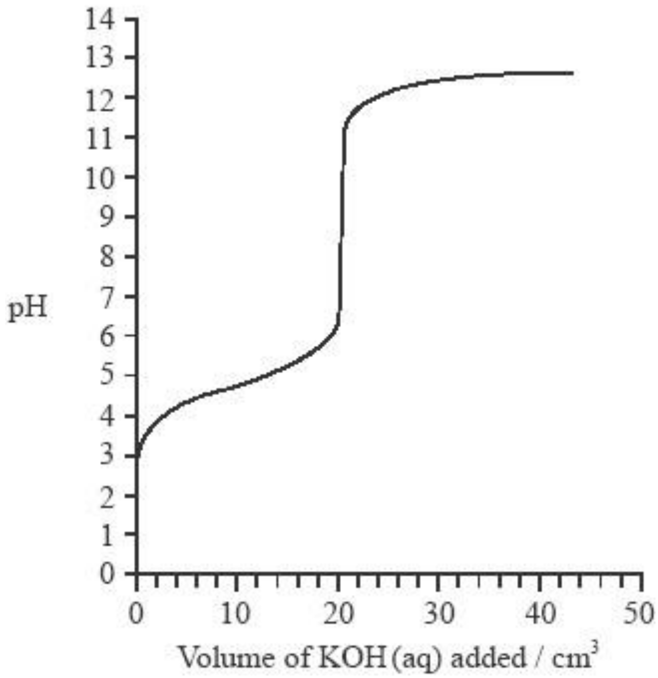
(Total 1 mark)

3. Which compounds can be mixed together as solutions of equal volume and concentration to form a buffer solution?

A. Nitric acid and potassium hydroxide
B. Nitric acid and potassium nitrate
C. Propanoic acid and potassium hydroxide
D. Propanoic acid and potassium propanoate

(Total 1 mark)

4. The graph below indicates the pH change during the titration of 20.0 cm^3 of 0.100 mol dm^{-3} of CH_3COOH (aq) with 0.100 mol dm^{-3} KOH (aq). From the graph, identify the volume of KOH(aq) and the pH at the equivalence point.



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(Total 2 marks)

5. (i) Describe how an indicator works.

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(3)

6. Using Table 16 of the Data Booklet, identify the most appropriate indicator for the titration of ethanoic acid with potassium hydroxide. Explain your choice.

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(2)

(Total 5 marks)

7. Explain, using an equation, whether a solution of 0.10 mol dm^{-3} $FeCl_3(aq)$ would be acidic, alkaline or neutral.

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(Total 2 marks)

8. Determine the pH of the solution resulting when 100 cm^3 of 0.50 mol dm^{-3} $HCl(aq)$ is mixed with 200 cm^3 of 0.10 mol dm^{-3} $NaOH(aq)$.

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(Total 5 marks)

9. Based on information in the table below, which acid is the strongest?

A.
B.
C.

Acid	pK_a	K
HA	2.0	-
HB	–	1 × 1[illegible] −
HC	4.0	-
HD	–	1 × 1[illegible] −

(Total 1 mark)

10. pK_w for water at 10 °C = 14.54. What is the pH of pure water at this temperature?

A. 6.73
B. 7.00
C. 7.27
D. 7.54

(Total 1 mark)

11. Which aqueous solution has a pH less than 7?

A. $KNO_3(aq)$
B. $Na_2CO_3(aq)$
C. $[Fe(H_2O)_6]Cl_3(aq)$
D. $CH_3COONa(aq)$

(Total 1 mark)

12. What is the correct expression for the ionic product constant of water, K_w?

A. K_W $\frac{[H^+]}{[OH^-]}$ =

B. K_W =

C. K_W = $[H^+] + [OH^-]$

D. K_W $\frac{[H_2O]}{[H^+][OH^-]}$ = $[H^+][OH^-]$

(Total 1 mark)

13. Some of the most important processes in chemistry involve acid-base reactions.

(i) Calculate the K_a value of benzoic acid, C_6H_5COOH, using Table 15 in the Data Booklet.

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(1)

(ii) Based on its K_a value, state and explain whether benzoic acid is a strong or weak acid.

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(2)

14. Determine the hydrogen ion concentration and the pH of a 0.010 mol dm^{-3} benzoic acid solution. State one assumption made in your calculation.

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(4)

(Total 7 marks)

15. Which values are correct for a 0.010 mol dm^{-3} solution of NaOH(aq) at 298 K?

($K_w = 1.0\times10^{-14}$ mol^2 dm^{-6} at 298 K)

A. $[H^+] = 1.0\times10^{-12}$ mol dm^{-3} and pH = 12.00

B. $[OH^-] = 1.0\times10^{-12}$ mol dm^{-3} and pH = 12.00

C. $[H^+] = 1.0\times10^{-12}$ mol dm^{-3} and pOH = 12.00

D. $[OH^-] = 1.0\times10^{-12}$ mol dm^{-3} and pOH = 12.00

(Total 1 mark)

Topic 4: redox and electrochemistry

Topics:

- Definitions
- Redox reactions
- Half reactions
- Oxidation states
- Oxidizing and reducing agents
- Interpreting activity series
- Galvanic cells (also known as voltaic cells)
- Cell diagrams
- Standard reduction potentials
- The standard hydrogen electrode
- Using standard reduction potentials

Sample questions

Oxidation and Reduction (HL) Practice

1. Consider the following standard electrode potentials.

$Zn^{2+}(aq) + 2e^{-} \quad Zn(s)$ $\qquad E^{\ominus} = –0.76\ V$

$Cl_2(g) + 2e^{-} \quad 2Cl^{-}(aq)$ $\qquad E^{\ominus} = +1.36\ V$

$Mg^{2+}(aq) + 2e^{-} \quad Mg(s)$ $\qquad E^{\ominus} = –2.37\ V$

What will happen when zinc powder is added to an aqueous solution of magnesium chloride? A.

No reaction will take place.

B. Chlorine gas will be produced.

C. Magnesium metal will form.

D. Zinc chloride will form.

(Total 1 mark)

2. What are the features of a standard hydrogen electrode?

I. A temperature of 298 K

II. A carbon electrode

III. Hydrogen gas at 1.01×10^5 Pa (1 atm) pressure

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

(Total 1 mark)

3. Deduce the equations for the formation of the major product at the positive electrode (anode) when the following aqueous solutions are electrolysed.

- dilute sodium chloride
- concentrated sodium chloride

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(Total 2 marks)

4. A voltaic cell is constructed from two half-cells as illustrated below.

(i) Use Table 14 of the Data Booklet to deduce the equation for the spontaneous reaction occurring in this cell.

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(1)

(ii) Calculate the standard potential for this cell.

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(1)

(iii) State the conditions necessary for the potential of the cell to equal that calculated in part (ii) using the data from Table 14.

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(1)
(Total 3 marks)

5. Using the data below and data from Table 14 of the Data Booklet, predict and explain which metal, cadmium or chromium, may be obtained by electrolysis of separate aqueous solutions of Cd^{2+}(aq) ions and Cr^{2+}(aq) ions.

$E^{\ominus}$ / V	
$Cd^{2+}(aq) + 2e^- \rightarrow Cd(s)$	–0.40
$Cr^{2+}(aq) + 2e^- \rightarrow Cr(s)$	–0.91

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(Total 2 marks)

6. (i) Electrolysis is used in the electroplating of metals. The same amount of current is passed through separate aqueous solutions of $NiSO_4$, $Sn(SO_4)_2$ and $Cr_2(SO_4)_3$ in separate electrolytic cells for the same amount of time. State and explain which cell would deposit the greatest amount (in mol) of metal. Identify the electrode at which the metal is deposited.

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(3)

(ii) For the $Sn(SO_4)_2$ cell, suggest **two** factors, other than time and current, that would affect the amount of metal deposited during electroplating.

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(2)
(Total 5 marks)

7. The standard electrode potentials for two metals are given below.

$Al^{3+}(aq) + 3e^{-}$ $Al(s)$ $E^{\ominus} = -1.66$ V $Ni^{2+}(aq) + 2e^{-}$ $Ni(s)$
$E^{\ominus} = -0.23$ V

What is the equation and cell potential for the spontaneous reaction that occurs?

A. $2Al^{3+}(aq) + 3Ni(s) \rightarrow 2Al(s) + 3Ni^{2+}(aq)$ $E^{\ominus} = 1.89$ V

B. $2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$ $E^{\ominus} = 1.89$ V

C. $2Al^{3+}(aq) + 3Ni(s) \rightarrow 2Al(s) + 3Ni^{2+}(aq)$ $E^{\ominus} = 1.43$ V

D. $2Al(s) + 3Ni^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Ni(s)$ $E^{\ominus} = 1.43$ V

(Total 1 mark)

8. The same quantity of electricity was passed through separate molten samples of sodium bromide, NaBr, and magnesium chloride, $MgCl_2$. Which statement is true about the amounts, in mol, that are formed?

A. The amount of Mg formed is equal to the amount of Na formed.

B. The amount of Mg formed is equal to the amount of Cl_2 formed.

C. The amount of Mg formed is twice the amount of Cl_2 formed.

D. The amount of Mg formed is twice the amount of Na formed.

(Total 1 mark)

9. The standard electrode potential for a half-cell made from iron metal in a solution of iron(II) ions, Fe^{2+}(aq), has the value –0.45 V.

(i) Define *standard electrode potential*.

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(2)

(ii) Explain the significance of the minus sign in –0.45 V.

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(1)

(Total 3 marks)

10. Consider the following table of standard electrode potentials.

***E*^ө / V**	
Fe^{2+}(aq) + 2e⁻ Fe(s)	–0.45
Sn^{2+}(aq) +	–0.14

$2e^-$ Sn(s)	
H^+(aq) + e^- H_2(g)	0.00
Sn^{4+}(aq) + $2e^-$ Sn^{2+}(aq)	+0.15
Fe^{3+}(aq) + e^- Fe^{2+}(aq)	+0.77
Ag^+(aq) + e^- Ag(s)	+0.80
Br_2(l) + e^- Br^-(aq)	+1.07

From the list above:

(i) State the species which is the strongest oxidizing agent.

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(1)

(ii) Deduce which species can reduce Sn^{4+}(aq) to Sn^{2+}(aq) but will not reduce Sn^{2+}(aq) to Sn(s) under standard conditions.

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(1)

(iii) Deduce which species can reduce Sn^{2+}(aq) to Sn(s) under standard conditions.

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(1)
(Total 3 marks)

11. Sodium metal can be obtained by the electrolysis of molten sodium chloride.

(i) Explain why it is very difficult to obtain sodium from sodium chloride by any other method.

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(2)

(ii) Explain why an aqueous solution of sodium chloride cannot be used to obtain sodium metal by electrolysis.

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(2)
(Total 4 marks)

12. (a) (i) Draw an annotated diagram of a voltaic cell composed of a magnesium electrode in 1.0 mol dm^{-3} magnesium nitrate solution and a silver electrode in 1.0 mol dm^{-3} silver nitrate solution. State the direction of electron flow on your diagram.

(4)

(ii) Deduce half-equations for the oxidation and reduction reactions.

(2)

(iii) Using Table 14 of the Data Booklet, calculate the cell potential for this cell.

(2)

(b) The standard electrode potentials for three other electrode systems are given below.

	$E^\ominus$/ V
$MnO_4^-(aq) + 8H^+(aq) + 5e^-$ $Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$Fe^{3+}(aq) + e^-$ $Fe^{2+}(aq)$	+0.77
$Cd^{2+}(aq) + 2e^-$ $Cd(s)$	–0.40

(i) Identify which species in the table above is the best reducing agent.

(1)

(ii) Deduce the equation for the overall reaction with the greatest cell potential.

(2)

(c) These values were obtained using a standard hydrogen electrode. Describe the materials and conditions used in the standard hydrogen electrode. (A suitably labelled diagram is acceptable).

(4)

(Total 15 marks)

13. (i) Solid sodium chloride does not conduct electricity but molten sodium chloride does. Explain this difference.

(2)

(ii) Outline what happens in an electrolytic cell during the electrolysis of molten sodium chloride using inert electrodes. Deduce equations for the reactions occurring at each electrode.

(4)

(iii) Two electrolytic cells are connected in series as shown in the diagram below. In one there is molten magnesium chloride and in the other, dilute sodium hydroxide solution. Both cells have inert electrodes. If 12.16 g of magnesium is produced in the first cell, deduce the identity and mass of products produced at the positive and negative electrodes in the second cell.

(4)
(Total 10 marks)

14. Consider the following standard electrode potentials.

$Cr^{3+}(aq) + 3e^{-} \rightarrow Cr(s)$ $E^{\ominus} = -0.74$ V $Fe^{3+}(aq) + e^{-} \rightarrow Fe^{2+}(aq)$ $E^{\ominus} = +0.77$ V

What will be the cell potential, in V, of a voltaic cell in which the following reaction takes place?

$$Cr(s) + 3Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq) + Cr^{3+}(aq)$$

A. –1.51

B. –0.03

C. +0.03

D. +1.51

(Total 1 mark)

15. (i) **Molten** sodium chloride is electrolysed in a cell using inert electrodes. State the halfequation, with state symbols, for the reaction taking place at the positive electrode (anode) and for the reaction taking place at the negative electrode (cathode). Determine the mole ratio of the products formed.

(3)

(ii) Predict and explain the products of electrolysis of a **concentrated** solution of NaCl(aq) using inert electrodes. Your answer should include half-equations with state symbols for the reaction at **each** electrode.

(4)
(Total 7 marks)

16. Electroplating is an important application of electrolytic cells with commercial implications. Copper may be plated using an electrolytic cell with an aqueous acidified copper(II) sulfate electrolyte.

For the copper plating of tin to make jewelry, state the half-equation at **each** electrode. Assume the other electrode is also inert. Suggest **two** observations that you would be able to make as the electroplating progresses.

(Total 4 marks)

17. The following equations indicate reactions that occur spontaneously.

$$Fe(s) + NiCl_2(aq) \rightarrow FeCl_2(aq) + Ni(s)$$

$$Zn(s) + FeCl_2(aq) \rightarrow ZnCl_2(aq) + Fe(s)$$

$$Ni(s) + PbCl_2(aq) \rightarrow NiCl_2(aq) + Pb(s)$$

Which is the **increasing** order of the reactivity of the metals?

A. Fe < Ni < Zn < Pb

B. Pb < Ni < Fe < Zn

C. Ni < Zn < Pb < Fe

D. Zn < Fe < Ni < Pb

(Total 1 mark)

18. A voltaic cell is made by connecting two half-cells represented by the half-equations below.

$Mn^{2+}(aq) + 2e^- \rightarrow Mn(s)$ $E^\ominus = -1.19$ V $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$ $E^\ominus = -0.13$ V

Which statement is correct about this voltaic cell?

A. Mn is oxidized and the voltage of the cell is 1.06 V.

B. Pb is oxidized and the voltage of the cell is 1.06 V.

C. Mn is oxidized and the voltage of the cell is 1.32 V.

D. Pb is oxidized and the voltage of the cell is 1.32 V.

(Total 1 mark)

19. For the electrolysis of aqueous copper(II) sulfate, which of the following statements is correct?

A. Cu and O_2 are produced in a mol ratio of 1:1 B.

H_2 and O_2 are produced in a mol ratio of 1:1

C. Cu and O_2 are produced in a mol ratio of 2:1

D. H_2 and O_2 are produced in a mol ratio of 2:1

(Total 1 mark)

20. Magnesium can be produced from the electrolysis of molten magnesium chloride, $MgCl_2$.

(i) Explain how molten magnesium chloride conducts an electric current.

(2)

(ii) Identify the electrode where oxidation occurs during electrolysis of molten magnesium chloride and state an equation for the half-reaction.

(2)

(iii) Explain why magnesium is not formed during the electrolysis of aqueous magnesium chloride solution.

(1)
(Total 5 marks)