KEY

1. REACTION KINETICS

Introduction

A1. give examples of reactions proceeding at different rates
0106-MC1-A1

1. Which of the following reactions is slowest at room temperature? **(1 mark)**

A. $NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$
✓ B. $MgCl_{2(s)} + Ca_{(s)} \rightarrow Mg_{(s)} + CaCl_{2(s)}$
C. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(\ell)}$
D. $Ba(NO_3)_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaNO_{3(aq)}$

A2. describe rate in terms of some quantity (produced or consumed) per unit of time
0108-MC01-A2 → incorrect exam given

1. Consider the following reaction:

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

If the rate of formation of NH_3 is 4.0×10^{-4} mol/s, then the rate of consumption of H_2 is

$$4.0\times10^{-4}\ \frac{\text{mol } NH_3}{s} \times \frac{3\text{ mol } H_2}{2\text{ mol } NH_3} = 6.0\times10^{-4}\ \frac{\text{mol}}{s}\ H_2$$

A. 2.0×10^{-4} mol/s
B. 4.0×10^{-4} mol/s
✓ C. 6.0×10^{-4} mol/s
D. 1.2×10^{-3} mol/s

A3. experimentally determine rate of a reaction
9901-MC1-A3

1. Consider the reaction:

$$Ca_{(s)} + 2H_2O_{(\ell)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$$

At a certain temperature, 2.50 g Ca reacts completely in 30.0 seconds. The rate of consumption of Ca is

① $2.50\text{ g Ca} \times \frac{1\text{ mol}}{40.1\text{ g}} = 0.06234\text{ m}$

② $\frac{0.06234\text{ mol}}{0.500\text{ min}} = 0.1247\ \frac{\text{mol}}{\text{min}}$

A. 0.00208 mol/min
B. 0.0833 mol/min
✓ C. 0.125 mol/min
D. 5.00 mol/min

A4. identify properties that could be monitored in order to determine a reaction rate
0106-MC2-A4

2. Consider the following reaction: **(1 mark)**

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

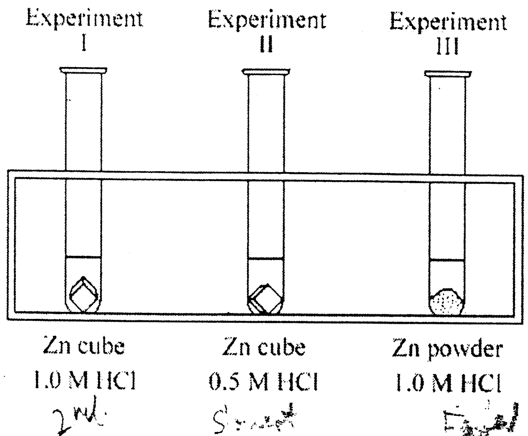
Which of the following could be used to determine reaction rate in a closed system?

Assume no product $t=0$
∴ increase in pressure

A. a decrease in gas pressure
✓ B. an increase in gas pressure
C. a decrease in the mass of the system
D. an increase in the mass of the system

A5. recognize some of the factors that control reaction rates
0006-MC4-A5

4. Consider the following experiments, each involving equal masses of zinc and 10.0 mL of acid:



The rate of reaction in order from fastest to slowest is

A. I > II > III
B. II > I > III
C. III > I > II ✓
D. III > II > I

A6. compare and contrast factors affecting the rates of both homogeneous and heterogeneous reactions
0108–MC2–A6

2. Consider the following reaction: **(1 mark)**

$$3Fe_2O_{3(s)} + CO_{(g)} \rightarrow 2Fe_3O_{4(s)} + CO_{2(g)} + 46\text{ kJ}$$

Which of the following would cause the rate of the reaction to increase?

A. removing the Fe_3O_4
B. decreasing the temperature
C. increasing the surface area of Fe_2O_3 ✓
D. increasing the volume of the reaction vessel

A7. discuss situations in which the rate of reaction must be controlled
No Examples Found!

Collision Theory

B1. demonstrate an awareness of the following:
- reactions are the result of collisions between reactant particles
- not all collisions are successful
- sufficient kinetic energy (KE) and favourable geometry are required
- to increase the rate of a reaction one must increase the frequency of successful collisions
- energy changes are involved in reactions as bonds are broken and formed

0004-MC3-B1

3. Which of the following changes will increase the average kinetic energy of reactant molecules?

= T temperature

A. adding a catalyst
B. increasing the temperature ✓
C. increasing the surface area
D. increasing the concentration

B2. describe the activated complex in terms of its potential energy (PE), stability, and structure
0008-MC4-B2

4. Which of the following is true for an activated complex?

A. stable and has low PE
B. stable and has high PE
C. unstable and has low PE
D. unstable and has high PE

B3. define *activation energy*
0108-MC3-B3

3. *Activation energy* is described as **(1 mark)**

A. the energy of the activated complex.
B. a point on the PE diagram where KE = PE.
C. the unstable high PE structural arrangement of atoms.
D. the minimum PE difference between the activated complex and the reactants.

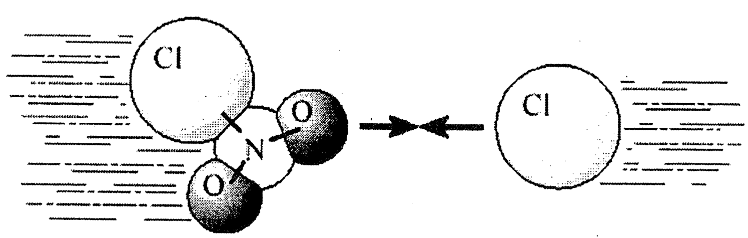
B4. describe the relationship between activation energy and rate of reaction
0104-MC5-B4

5. What is the relationship between the activation energy and the rate of a reaction? **(1 mark)**

A. When the activation energy is high, the rate of reaction is fast.
B. When the activation energy is low, the rate of reaction is slow.
C. When the activation energy is high, the rate of reaction is slow.
D. There is no relationship between activation energy and rate of reaction.

B5. describe the changes in KE and PE as reactant molecules approach each other
0106-MC5-B5

5. The following diagram shows reactant molecules approaching one another: **(2 marks)**

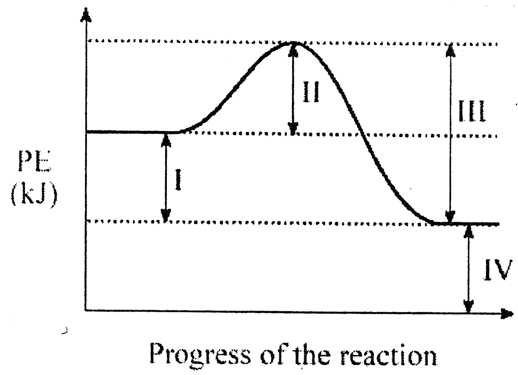


What is happening to the kinetic energy and the potential energy?

	Kinetic Energy	Potential Energy
A.	decreasing	decreasing
B.	decreasing	increasing
C.	increasing	increasing
D.	increasing	decreasing

B6. draw and label PE diagrams for both exothermic and endothermic reactions, including $\triangle H$, activation energy, and the energy of the activated complex
0104-MC4-B6

4. Consider the following PE diagram: **(1 mark)**

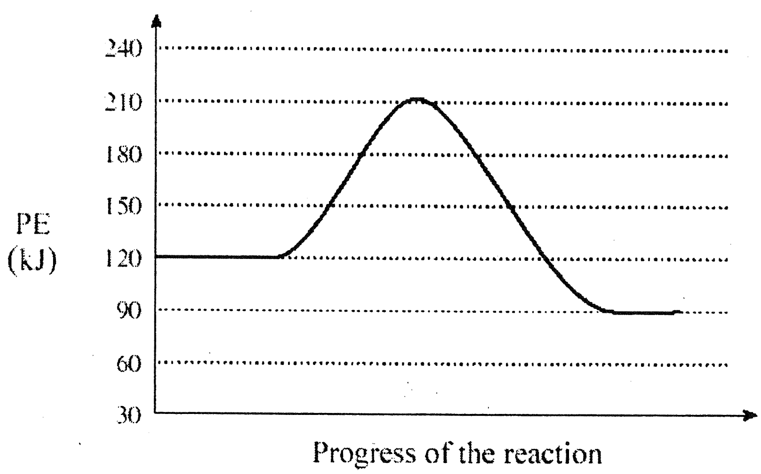


The activation energy for the forward reaction is represented by

A. I
B. II
C. III
D. IV

B7. relate the sign of $\triangle H$ to whether the reaction is exothermic or endothermic
0108-MC5-B7

5. Consider the following potential energy diagram for a reaction: **(1 mark)**



What is the value of ΔH for this reaction?

A. −120 kJ
B. −30 kJ
C. +30 kJ
D. +120 kJ

B8. write a chemical equation including the energy term (given a △H value) and vice versa
0106-MC4-B8

4. Which of the following reactions is endothermic? **(1 mark)**

A. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(\ell)} + 890.3\ kJ$

B. $2Na_2O_{2(s)} + 2H_2O_{(\ell)} - 287.0\ kJ \rightarrow 4NaOH_{(aq)} + O_{2(g)}$

C. $CaO_{(s)} + H_2O_{(\ell)} \rightarrow Ca(OH)_{2(aq)}$ $\Delta H = -65.2\ kJ$

D. $CaO_{(s)} + 3C_{(s)} \rightarrow CaC_{2(s)} + CO_{(g)}$ $\Delta H = +464.8\ kJ$

B9. describe the role of the following factors in reaction rate:
- nature of reactants
- concentration
- temperature
- surface area

0001-MC5-B9

5. Increasing the temperature of a reaction increases the reaction rate by

I.	increasing frequency of collisions
II.	increasing the kinetic energy of collision
III.	decreasing the potential energy of collision

A. I only.
B. I and II only.
C. II and III only.
D. I, II and III.

Reaction Mechanisms and Catalysts

C1. use examples to demonstrate that most reactions involve more than one step
No examples found

C2. describe a reaction mechanism as the series of steps (collisions) that result in the overall reaction
9901-W1-C2

1. Consider the following reaction mechanism:

tricky!

Step 1	?
Step 2	$H_2 + Cl \rightarrow HCl + \cancel{H}$
Step 3	$\cancel{H} + \cancel{Cl_2} \rightarrow HCl + \cancel{Cl}$
Step 4	$\cancel{Cl} + Cl \rightarrow \cancel{Cl_2}$
Overall	$H_2 + Cl_2 \rightarrow 2HCl$

a) Write the equation for Step 1. **(2 marks)**

✓ $Cl_2 \rightarrow 2Cl$

b) Identify the reaction intermediate(s). **(1 mark)**

✓ Cl and H

C3. define *catalyst*
0101-MC6-C3
6. A substance that increases the rate of a reaction without appearing in the equation for the overall reaction is a(n) **(1 mark)**

A. product.
B. catalyst.
C. reactant.
D. intermediate.

C4. compare and contrast the PE diagrams for a catalyzed and uncatalyzed reaction in terms of:
- reaction mechanism
- ΔH
- activation energy

0108-MC4-C4
4. What happens to the activation energy and ΔH when a catalyst is added to a reaction? **(2 marks)**

	Activation Energy	ΔH
A.	increases	remains the same
B.	increases	increases
C.	decreases	remains the same
D.	decreases	decreases

C5. identify reactant, product, reaction intermediate, and catalyst from a given reaction mechanism
0108-MC6-C5
6. A substance that is produced in one step in a reaction mechanism and consumed in a subsequent step, without appearing in the overall reaction, is a(n) **(1 mark)**

A. catalyst.
B. product.
C. reactant.
D. intermediate.

C6. describe the uses of specific catalysts in a variety of situations
No examples found

End of Chemistry 12 – Unit 1: Reaction Kinetics Section

KEY

2. DYNAMIC EQUILIBRIUM

Introduction

D1. describe the reversible nature of most chemical reactions
0004-MC7-D1,4

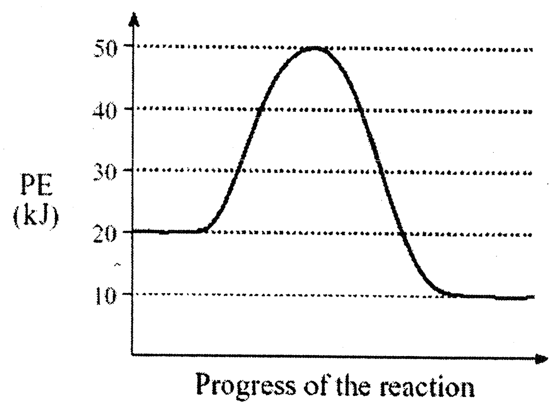
7. Which of the following applies to a chemical equilibrium?

I.	Forward and reverse reaction rates are equal
II.	Equilibrium can be achieved from either direction
III.	Macroscopic properties are constant

A. I only
B. I and II only
C. II and III only
D. I, II and III

D2. identify the reversible pathways of a chemical reaction on the PE diagram
9904-MC7-D2

7. Consider the following PE diagram for a reversible reaction:



$E_a(f) = 30\text{ kJ}$
$E_a(r) = 40\text{ kJ}$
$\Delta H_f = -10\text{ kJ}$
$\Delta H_r = +10\text{ kJ}$

Which of the following describes this reaction?

	DIRECTION	ACTIVATION ENERGY (kJ)	ΔH (kJ)
A.	reverse	30	−10
B.	forward	40	−10
C.	forward	30	+10
D.	reverse	40	+10

D3. relate the changes in rates of the forward and reverse reactions to the changing concentrations of the reactants and products as equilibrium is established
0001-MC7-D3
7. Consider the following equilibrium:

$$N_{2(g)} + 2O_{2(g)} \rightleftarrows 2NO_{2(g)}$$

Equal moles of N_2 and O_2 are added, under certain conditions, to a closed container. Which of the following describes the changes in the reverse reaction which occur as the system proceeds toward equilibrium?

	Rate of Reverse Reaction	$[NO_2]$
A.	increases	increases
B.	decreases	increases
C.	increases	decreases
D.	decreases	decreases

(be careful - not the rate of change!)

D4. describe chemical equilibrium as a closed system at constant temperature:
- whose macroscopic properties are constant
- where the forward and reverse reaction rates are equal
- that can be achieved from either direction
- where the concentrations of reactants and products are constant

9804-MC5-D4
5. Consider the following:

I	forward and reverse rates are equal
II	macroscopic properties are constant
III	can be achieved from either direction
IV	concentrations of reactants and products are equal

Which of the above are true for all equilibrium systems?

A. I and II only
B. I and IV only
C. I, II and III only
D. II, III and IV only

D5. describe the dynamic nature of chemical equilibrium
9801-MC5-D5
5. Chemical equilibrium is said to be dynamic because

A. the reaction proceeds quickly.
B. the mass of the reactants is decreasing.
C. the macroscopic properties are constant.
D. both forward and reverse reactions are occurring.

D6. infer that a system not at equilibrium will tend to move toward a position of equilibrium (LeChatelier)
0006-MC7-D6
7. Consider the following equilibrium:

$$2NOCl_{(g)} \rightleftarrows 2NO_{(g)} + Cl_{2(g)}$$

A flask of fixed volume is initially filled with $NOCl_{(g)}$, $NO_{(g)}$ and $Cl_{2(g)}$. When equilibrium is reached, the pressure has increased. To reach equilibrium, the reaction proceeded to the

react → prod

A. left because Trial K_{eq} was less than K_{eq}.
B. right because Trial K_{eq} was less than K_{eq}.
C. left because Trial K_{eq} was greater than K_{eq}.
D. right because Trial K_{eq} was greater than K_{eq}.

$K_{eq} = \frac{[prod]}{[react]} \uparrow$

D7. determine entropy and enthalpy changes from a chemical equation (qualitatively)
9804-MC6-D7
6. In which reaction is the enthalpy of the reactants greater than the enthalpy of the products?

A. $H_2O_{(s)} \rightarrow H_2O_{(l)}$
B. $H_2O_{(s)} \rightarrow H_2O_{(g)}$
C. $H_2O_{(l)} \rightarrow H_2O_{(s)}$ (∵ releases heat)
D. $H_2O_{(l)} \rightarrow H_2O_{(g)}$

D8. state that systems tend toward a position of minimum enthalpy and maximum randomness (entropy)
0106-MC8-D8
8. The entropy of a system is a term used to describe **(1 mark)**

A. randomness.
B. heat content.
C. average kinetic energy.
D. stored chemical energy.

D9. predict the result when enthalpy and entropy factors:
- both favour the products
- both favour the reactants
- oppose one another

0101-MC8-D9
8. From the following, select the situation where both enthalpy and entropy favour the reaction toward products: **(1 mark)**

react → prod
when $\Delta H \downarrow$
$\Delta S \uparrow$

	Enthalpy	Entropy
A.	increasing	increasing
B.	increasing	decreasing
C.	decreasing	decreasing
D.	decreasing	increasing

Le Châtelier's Principle

E1. describe the term *shift* as it applies to equilibrium
No examples found!

E2. apply Le Châtelier's principle to the shifting of equilibrium involving the following:
- temperature change
- concentration change
- volume change of gaseous systems

0101-MC9-E2

9. Consider the following equilibrium: **(1 mark)**

$$2NO_{(g)} + Br_{2(g)} \rightleftarrows 2NOBr_{(g)} + \text{energy}$$

The equilibrium will shift to the left as a result of

A. adding a catalyst.

B. adding some $NO_{(g)}$

C. increasing the volume. (∴ ↓ pressure)

D. decreasing the temperature.

E3. explain the above shifts using the concepts of reaction kinetics

0101-MC10-E3

10. Consider the following equilibrium: Tricky **(2 marks)**

$$PCl_{3(g)} + 3NH_{3(g)} \rightleftarrows P(NH_2)_{3(g)} + 3HCl_{(g)}$$

The volume of the equilibrium system is increased and a new equilibrium is established. How have the rates been affected?

	Rate (forward)	Rate (reverse)
A.	increased	decreased
B.	decreased	increased
C.	decreased	decreased
D.	did not change	did not change

↑volume ∴ ↓ pressure
i.e. ↓ [ ]
We know [ ] affects rate.
↓ [ ] will ↓ rate
Since both sides ↓ [ ] ∴ both rates ↓
→ Tricky! No! why? see above!

E4. identify the effect of a catalyst on dynamic equilibrium

9801-MC8-E4

8. Addition of a catalyst to an equilibrium system

A. increases the value of K_{eq}.

B. increases the yield of products.

C. has no effect on the rates of reaction.

D. increases the rate of formation of both reactants and products.

E5. apply the concept of equilibrium to a commercial or industrial process
0106-MC10-E2,5

10. Consider the following equilibrium: **(1 mark)**

$$Ni_{(s)} + 4CO_{(g)} \rightleftarrows Ni(CO)_{4(g)} + NRG \quad \Delta H = -160.8\ kJ$$

re-write as NRG term

Which of the following will cause this equilibrium to shift to the left?

A. add some CO ✗
B. decrease the volume (∴ ↑ pressure) ✗
C. remove some $Ni(CO)_4$ ✗
D. increase the temperature (wants to get rid of XS heat NRG ✓

The Equilibrium Constant

F1. gather and interpret data on the concentration of reactants and products of a system at equilibrium
9808-MC9-F1

9. Consider the following equilibrium:

$$2HBr_{(g)} \rightleftarrows H_{2(g)} + Br_{2(g)}$$

* N.B

Initially, 0.100 mol HBr is placed into a 2.0 L container. At equilibrium, there are 0.040 mol HBr present. The equilibrium concentration of H_2 is

	$2HBr$	$\rightleftharpoons$	H_2	$+$	Br_2
i	0.05		0		0
c ∴	−0.03		+0.015		+0.015
e	0.02		+0.015		+0.015

A. 0.0050 mol/L
B. 0.010 mol/L
C. 0.015 mol/L ✓
D. 0.030 mol/L

F2. write the expression for the equilibrium constant when given the equation for either a homogeneous or heterogeneous equilibrium system
9801-MC9-F2

9. Consider the following reaction:

$$2B_{(s)} + 3F_{2(g)} \rightleftarrows 2BF_{3(g)}$$

$$K_{eq} = \frac{[BF_3]^2}{[F_2]^3}$$

The equilibrium expression is

A. $K_{eq} = \dfrac{[2BF_3]}{[3F_2]}$

B. $K_{eq} = \dfrac{[F_2]^3}{[BF_3]^2}$

C. $K_{eq} = \dfrac{[BF_3]^2}{[F_2]^3}$ ✓

D. $K_{eq} = \dfrac{[BF_3]^2}{[B]^2[F_2]^3}$

F3. relate the equilibrium position to the value of K_{eq} and vice versa
0101-MC11-F3

11. Starting with equal moles of reactants, which of the following equilibrium systems most favours the reactants? ie smallest K_{eq} **(1 mark)**

$K_{eq} = \frac{\text{prod}}{\text{react}}$

A. $SO_{2(g)} + NO_{2(g)} \rightleftarrows SO_{3(g)} + NO_{(g)}$ $K_{eq} = 3.4$

B. $CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$ $K_{eq} = 31.4$

C. $H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$ $K_{eq} = 10$

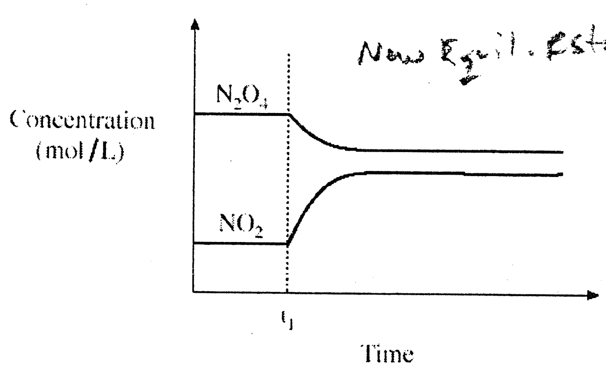
D. $N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)}$ $K_{eq} = 1.0 \times 10^{-31}$

F4. predict the effect (or lack of effect) on the value of K_{eq} of changes in the following factors: temperature, pressure, concentration, surface area, and catalyst
0101-MC12-F4

12. Consider the following equilibrium reaction: **(2 marks)**

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$

New Equil. established



heat applied and $[N_2O_4]\downarrow$ i.e. react $\downarrow$

$N_2O_4 \rightleftarrows 2NO_2$ $\longrightarrow$

$\therefore$ heat $+ N_2O_4 \rightleftarrows 2NO_2$

$\therefore$ endothermic

Also, reactive ↑ and [more] product (as)

$\therefore K_{eq} \uparrow$

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

F5. calculate the value of K_{eq} given the equilibrium concentration of all species
9806-MC11-F5

11. Consider the following:

$$C_{(s)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + H_{2(g)}$$

At equilibrium in a 1.0 L container, there are 1.60×10^{-2} mol C, 1.50×10^{-2} mol H_2O, 3.00×10^{-1} mol CO, and 1.00×10^{-1} mol H_2. The value of K_{eq} is

A. 0.500
B. 2.00
C. 80.0
D. 125

$K_{eq} = \frac{[H_2][CO]}{[H_2O]} = \frac{(1.00 \times 10^{-1})(3.00 \times 10^{-1})}{(1.50 \times 10^{-2})} =$

F6. calculate the value of K_{eq} given the initial concentrations of all species and one equilibrium concentration
9801MC11-F6

11. Consider the following equilibrium:

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$$

When 0.40 mol of PCl_3 and 0.40 mol of Cl_2 are placed in a 1.00 L container and allowed to reach equilibrium, 0.244 mol of PCl_5 are present. From this information, the value of K_{eq} is

A. 0.10
B. 0.30
C. 3.3
D. 10

$PCl_3 + Cl_2 \rightleftharpoons PCl_5$
I 0.40 0.40 0
C −0.244 −0.244 +0.244
E 0.156 0.156 0.244

$\therefore K_{eq} = \frac{[PCl_5]}{[PCl_3][Cl_2]} = \frac{(0.244)}{(0.156)^2}$

$= 10.03$

F7. calculate the equilibrium concentrations of all species given the value of K_{eq} and the initial concentrations
9806-MC12-F7

12. Consider the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 1.0 \times 10^{-2}$$

At equilibrium, the $[NO_2] = 2.0 \times 10^{-2}$ mol/L and the $[N_2O_4]$ is

A. 4.0×10^{-6} mol/L
B. 4.0×10^{-2} mol/L
C. 2.0 mol/L
D. 25 mol/L

$K_{eq} = \frac{[NO_2]^2}{[N_2O_4]}$

$\therefore [N_2O_4] = \frac{[NO_2]^2}{K_{eq}}$

$= \frac{(2.0 \times 10^{-2})^2}{1.0 \times 10^{-2}}$

$= 0.04$

$= 4 \times 10^{-2}$

F8. determine whether a system is at equilibrium, and if not, in which direction it will shift to reach equilibrium when given a set of concentrations for reactants and products
0101-MC13-F8

13. Consider the following: **(1 mark)**

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)} \qquad K_{eq} = 0.45 \text{ at } 227°C$$

Initially, a 1.00 L flask is filled with 0.100 mol PCl_3, 0.100 mol Cl_2, and 0.100 mol PCl_5 at 227°C. Use K_{Trial} to predict the change in $[Cl_2]$ as equilibrium is established.

	K_{Trial}	$[Cl_2]$
A.	$K_{Trial} > K_{eq}$	increases
B.	$K_{Trial} < K_{eq}$	increases
C.	$K_{Trial} > K_{eq}$	decreases
D.	$K_{Trial} < K_{eq}$	decreases

Ask ? will Equil shift L or R

$PCl_3 + Cl_2 \rightleftharpoons PCl_5$
0.100 0.100 0.100

$K_{trial} = \frac{(0.100)}{(0.100)^2}$

$= 10$

but K_{eq} is 0.45

$\therefore \frac{prod}{react} \downarrow$ because

k must decrease

$\therefore [Cl_2]$ will ↑

End of Chemistry 12 – Unit 2: Dynamic Equilibria Section

KEY

3. SOLUBILITY EQUILIBRIA

Concept of Solubility

G1. classify solutions as ionic or molecular given the formula of the solute

9806-MC13-G1

13. Which of the following dissolves in water to form an ionic solution?

A. O_2
B. SiO_2
C. $KMnO_4$ ✓
D. $C_{12}H_{22}O_{11}$ → organic ∴ covalent.

metal + Non-metal = Ionic

G2. describe the conditions necessary to form a saturated solution

9904-MC15-G2

15. Consider the solubility equilibrium:

$$CaCO_{3(s)} \rightleftarrows Ca^{2+}_{(aq)} + CO_{3(aq)}^{2-}$$

An additional piece of solid $CaCO_3$ is added to the equilibrium above. The rate of dissolving and rate of crystallization have

	RATE OF DISSOLVING	RATE OF CRYSTALLIZATION
A. ✓	increased	increased
B.	increased	not changed
C.	not changed	increased
D.	not changed	not changed

Tricky!

← see next page (same question)

← No! Rates are still equal, but have Δ'd

G3. describe solubility as the concentration of a substance in a saturated solution

0001-MC14-G3

14. Which of the following does **not** define solubility?

A. the concentration of solute in a saturated solution
B. the moles of solute dissolved in a given volume of solution ✓ → nothing here about saturated
C. the maximum mass of solute that can dissolve in a given volume of solution
D. the minimum moles of solute needed to produce one litre of a saturated solution

G4. use appropriate units to represent the solubility of substances in aqueous solutions

9901-MC14-G4

14. Which of the following units could be used to describe solubility?

A. g/s
B. g/L ✓
C. M/L
D. mol/s

G5. measure the solubility of a compound in aqueous solution

0006-MC14-G5

14. A saturated solution of NaCl contains 36.5 g of solute in 0.100 L of solution. The solubility of the compound is

A. 0.062 M
B. 1.60 M
C. 3.65 M
D. 6.24 M ✓

M.M. (NaCl) = 58.5

① $36.5\,g \times \frac{1\,mol}{58.5\,g} = 0.624\,mol$

② $\frac{0.624\,mol}{0.100\,L} = 6.24\,M$

G6. describe the equilibrium that exists in a saturated aqueous solution
9801-MC13-G6

13. When solid AgBr is added to a saturated solution of AgBr, the reaction rates can be described as:

	RATE OF DISSOLVING	RATE OF CRYSTALLIZATION
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	increases	no change

G7. write a net ionic equation that describes a saturated solution
0008-MC16-G7

16. The net ionic equation that describes a saturated solution of Ag_2CrO_4 is

A. $Ag_2CrO_{4(s)} \rightleftarrows Ag_2CrO_{4(aq)}$

B. $Ag_2CrO_{4(s)} \rightleftarrows 2Ag^+_{(aq)} + CrO_4{}^{2-}_{(aq)}$

C. $Ag_2CrO_{4(s)} \rightleftarrows 2Ag^+_{(aq)} + Cr^{6+}_{(aq)} + 4O^{2-}_{(aq)}$

D. $2Ag^+_{(aq)} + CrO_4{}^{2-}_{(aq)} + 2H_2O_{(\ell)} \rightleftarrows 2AgOH_{(s)} + H_2CrO_{4(aq)}$

G8. calculate the concentration of the positive and negative ions given the concentration of a solute in an aqueous solution
0101-MC17-G8

17. The concentrations of the cation and anion in 0.40 M $(NH_4)_2Cr_2O_{7(aq)}$ are

	Cation	Anion
A.	0.40 M	0.40 M
B.	0.40 M	0.80 M
C.	0.80 M	0.40 M
D.	0.80 M	0.80 M

Solubility and Precipitation

H1. describe a compound as having high or low solubility relative to 0.1 M by using a solubility chart
9806-MC15-H1

15. Which of the following is most soluble?

A. Na_2S soluble
B. $CaSO_4$ low
C. $PbCO_3$ low
D. $Zn(OH)_2$ low

Use Solubility charge

H2. use a solubility chart to predict if a precipitate will form when two solutions are mixed, and identify the precipitate
9808-MC15-H2

15. Which of the following 0.20 M solutions will **not** form a precipitate when mixed with an equal volume of 0.20 M $Sr(OH)_2$?

	Ca : S	NH_4 : Cl	Na : SO_4	Ba : NO_3
Sr	— Sol	— sol	— low	—
OH	low —	sol —	sol —	low —
	No!	yes.	No.	No!

A. CaS
✓(B.) NH_4Cl
C. Na_2SO_4
D. $Ba(NO_3)_2$

H3. write a formula equation, complete ionic equation, and net ionic equation that represent a precipitation reaction
9901-MC16-H3

16. When equal volumes of 0.20 M $CuSO_4$ and 0.20 M Li_2S are combined, the complete ionic equation is

A. $Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow CuS_{(s)}$
B. $CuSO_{4(aq)} + Li_2S_{(aq)} \rightarrow CuS_{(s)} + Li_2SO_{4(aq)}$??
C. $Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2Li^+_{(aq)} + S^{2-}_{(aq)} \rightarrow Li_2SO_{4(aq)} + CuS_{(s)}$
✓(D.) $Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + 2Li^+_{(aq)} + S^{2-}_{(aq)} \rightarrow CuS_{(s)} + 2Li^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

none of these! Q: Is Li_2SO_4 soluble? yes

H4. use a solubility chart to predict if ions can be separated from solution through precipitation, and outline the process
0006-MC17-H4

17. A solution contains both Ag^+ and Mg^{2+} ions. During selective precipitation, these ions are removed one at a time by adding

✓(A.) I^- followed by OH^- AgI ppt and $Mg(OH)_2$ ppt
B. OH^- followed by S^{2-} No, both ppt
C. SO_4^{2-} followed by Cl^- No, Ag^+ ppt with SO_4^{2-}, but Mg^{2+} does not with Cl^-
D. NO_3^- followed by PO_4^{3-} No NO_3^- will not ppt

H5. predict qualitative changes in the solubility equilibrium upon the addition of a common ion
0008-MC19-H5

19. The solute AgBr is least soluble in

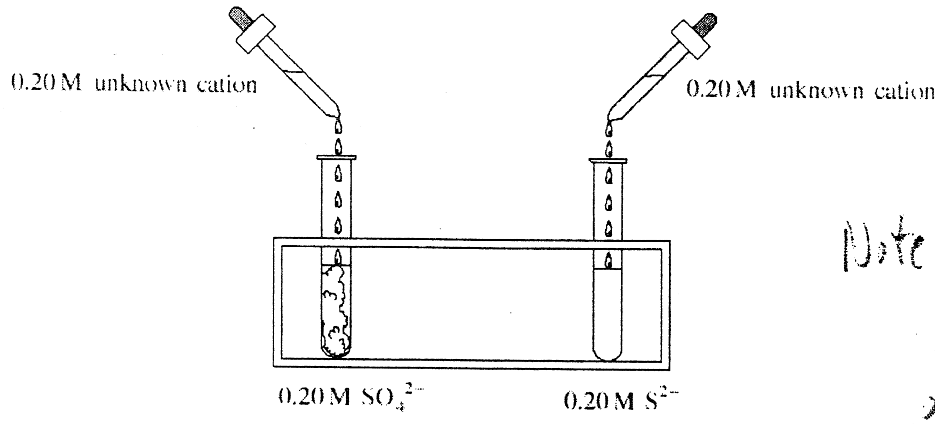
$AgBr \rightleftharpoons Ag^+ + Br^-$

3 Br^-

A. H_2O
✓(B.) 1.0 M $FeBr_3$
C. 1.0 M $CaBr_2$
D. 1.0 M $AgNO_3$

H6. identify an unknown ion through experimentation involving a qualitative analysis scheme
0104-MC19-H6

19. A precipitate forms when a 0.20 M solution containing an unknown cation is added to SO_4^{2-}, but not when an equal volume is added to S^{2-}. **(2 marks)**



Note: using 0.20 M so ... 0.10 M so use solubility table (semi-quantitative)

The unknown cation is

A. Na^+
B. Ca^{2+}
C. Pb^{2+}
D. Zn^{2+}

	Na^+	Ca^{2+}	Pb^{2+}	Zn^{2+}
SO_4^{2-}	sol	low	low	sol
S^{2-}	sol	sol	low	low

H7. devise a procedure by which the contaminating ions in hard or polluted water can be removed
9808-MC17-H7

17. Two ions found in hard water are Ca^{2+} and Mg^{2+}. Which of the following will precipitate only one of these ions?

A. I^-
B. S^{2-}
C. SO_4^{2-}
D. CO_3^{2-}

	I^-	S^{2-}	SO_4^{2-}	CO_3^{2-}
Ca^{2+}	sol	sol	low	low
Mg^{2+}	sol	sol	sol	low

Quantitative Aspects

I1. describe the K_{sp} expression as a specialized K_{eq} expression
9806MC17-I1

17. Which of the following saturated solutions has the lowest $[SO_4^{2-}]$ at 25°C ?

A. $SrSO_4$ 3.4×10^{-7}
B. $PbSO_4$ 1.8×10^{-8}
C. $CaSO_4$ 7.1×10^{-5}
D. $BaSO_4$ 1.1×10^{-10}

$K_{sp} = [\ ][\ ]$
∴ low K_{sp} = low [ ]
∴ use table of K_{sp}'s

I2. write a K_{sp} expression for a solubility equilibrium
9901-MC17-I2

17. The K_{sp} expression for a saturated solution of Ag_2CO_3 is

A. $K_{sp} = [Ag_2^+][CO_3^{2-}]$
B. $K_{sp} = [Ag^+]^2[CO_3^{2-}]$ ✓
C. $K_{sp} = [2Ag^+][CO_3^{2-}]$
D. $K_{sp} = [2Ag^+]^2[CO_3^{2-}]$

$Ag_2CO_3 \rightleftharpoons 2Ag^+ + CO_3^{2-}$
$Ksp = [Ag^+]^2[CO_3^{2-}]$

AB_2

I3. calculate the K_{sp} for AB and AB 2 type compounds when given the solubility of a compound
9901-MC18-I3

18. The solubility of FeF_2 is 8.4×10^{-3} M. The K_{sp} value is

A. 5.9×10^{-7}
B. 2.4×10^{-6} ✓
C. 7.1×10^{-5}
D. 8.4×10^{-3}

$FeF_2 \rightleftharpoons Fe^{2+} + 2F^-$
8.4×10^{-3}
$Ksp = [Fe^{2+}][F^-]^2$
$= (8.4\times10^{-3})(2\times8.4\times10^{-3})^2$
$= 2.37\times10^{-6}$

I4. calculate the solubility of AB and AB 2 type compounds from the K_{sp}
9904-MC20-I4

20. The solubility of SrF_2 is

A. 4.3×10^{-9} M
B. 6.6×10^{-5} M
C. 1.0×10^{-3} M ✓
D. 1.6×10^{-3} M

$Ksp = 4.3\times10^{-9}$
$= (x)(2x)^2$
$= 4x^3$
$\therefore x = \text{solubility} = 1.02\times10^{-3}$

$SrF_2 \rightleftharpoons Sr^{2+} + 2F^-$
$x \quad 2x$

I5. predict the formation of a precipitate by comparing the trial ion product to the K_{sp} value using specific data
9901-MC19-I5

19. If the Trial Ion Product for $AgBrO_3$ is calculated to be 1.0×10^{-7}, then

A. a precipitate forms because the Trial Ion Product > K_{sp}
B. a precipitate forms because the Trial Ion Product < K_{sp}
C. no precipitate forms because the Trial Ion Product > K_{sp}
D. no precipitate forms because the Trial Ion Product < K_{sp} ✓

$Ksp = 5.3\times10^{-5}$
$\therefore Q < Ksp$
$\therefore$ no ppt

I6. calculate the maximum concentration of one ion given the K_{sp} and the concentration of the other ion
9906-MC18-I6

18. The maximum $[SO_4^{2-}]$ that can exist in 1.0×10^{-3} M $Ca(NO_3)_2$ without a precipitate forming is

A. 7.1×10^{-5} M
B. 1.0×10^{-3} M
C. 8.4×10^{-3} M
D. 7.1×10^{-2} M ✓

ppt $\to CaSO_4$
$Ksp = 7.1\times10^{-5}$
$\therefore [Ca^{2+}] = 1.0\times10^{-3}$ M
$Ksp = 7.1\times10^{-5} = [Ca^{2+}][SO_4^{2-}]$
$[SO_4^{2-}] = \frac{Ksp}{[Ca^{2+}]} = \frac{7.1\times10^{-5}}{1.0\times10^{-3}} = 7.1\times10^{-2}$

I7. demonstrate and describe a method for determining the concentration of a specific ion
9806-W4-I7

4. Consider the following net ionic equation:

$$Ag^+_{(aq)} + SCN^-_{(aq)} \rightarrow AgSCN_{(s)}$$

3 sf

A 20.00 mL sample of 0.200 M NH_4SCN is used to titrate a 30.00 mL sample containing Ag^+. Calculate the $[Ag^+]$ in the original sample. **(3 marks)**

concept of titration (equivalence)

1) Convert vol x molarity into moles

$0.02000 \text{ L} \times 0.200 \frac{\text{mol}}{\text{L}} = .004 \text{ mol } SCN^-$

2) Interpret equation in terms of moles

$\frac{Ag^+}{SCN^-} = \frac{1}{1}$ ∴ mol Ag^+ = mol SCN^- = .004 mol

3) Convert back to [ ]

$\frac{.004 \text{ mol } Ag^+}{.030 \text{ L}} = 1.3333 \times 10^{-1} \text{ M}$

total vol = 20 + 30 = 50 mL
But Be careful! we want the original sample volume = 30.00 mL

4) Check s.f. (need 3 sf in answer)

$\boxed{[Ag^+] = 1.33 \times 10^{-1} \text{ M}}$ in original sample!

End of Chemistry 12 – Unit 3: Solubility Equilibria Section

KEY

4. ACIDS, BASES, AND SALTS

Properties and Definitions

J1. identify acids and bases through experimentation
9906-MC19-J1

4.00

19. A 1.0×10^{-4} M solution has a pH of 10.00. The solute is a

pH → ... strong!

HA → A^- + H^+

- A. weak acid.
- B. weak base.
- C. strong acid.
- D. strong base.

J2. list general properties of acids and bases
9808-MC21-J2

21. Both acidic and basic solutions

- A. taste sour.
- B. feel slippery.
- C. conduct electricity.
- D. turn blue litmus red.

J3. write balanced equations representing the neutralization of acids by bases in solution
0108-MC21-J3

21. Which of the following reactions is not a neutralization reaction?

- A. $KOH + HF \rightarrow KF + H_2O$
- B. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- C. $Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$
- D. $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$

J4. define *Arrhenius acids* and *bases*
9908-MC22-J4

22. An Arrhenius acid is defined as a chemical species that

- A. is a proton donor.
- B. is a proton acceptor.
- C. produces hydrogen ions in solution.
- D. produces hydroxide ions in solution.

J5. write names and formulae of some common acids and bases and outline some of their common properties, uses, and commercial names
No Examples Found!

J6. define *Brönsted-Lowry acids and bases*
9804-MC21-J6

21. Which of the following could act as a Brönsted-Lowry acid, but not as a Brönsted-Lowry base?

proton acceptor

- A. $NH_{3(aq)}$
- B. $H_2O_{(l)}$
- C. $HClO_{4(aq)}$
- D. $HCO_3^-{}_{(aq)}$

J7. identify Brönsted-Lowry acids and bases in an equation
9901-MC21-J7

21. Consider the following acid-base equilibrium:

$$HCO_3^- + H_2O \rightleftarrows H_2CO_3 + OH^-$$

base acid acid base

In the reaction above, the Brönsted-Lowry acids are

A. H_2O and OH^-
B. HCO_3^- and OH^-
C. H_2O and H_2CO_3
D. HCO_3^- and H_2CO_3

J8. write balanced equations representing the reaction of acids or bases with water
0006-MC23-J8

23. The predominant acid-base reaction between H_2O_2 and H_2O is

A. $H_2O_2 + H_2O \rightarrow 3OH^- + H^+$
B. $H_2O_2 + H_2O \rightarrow 2H_2O + O^{2-}$
C. $H_2O_2 + H_2O \rightarrow H_3O_2^+ + OH^-$
D. $H_2O_2 + H_2O \rightarrow H_3O^+ + HO_2^-$ from acid-base table

J9. identify an H_3O^+ ion as a protonated H_2O molecule represented in shortened form as H^+ (aq)
0106-MC21-J9

21. A hydronium ion has the formula

A. H_2^+
B. OH^-
C. H_2O^+
D. H_3O^+

J10. define *conjugate acid-base pair*
0008-W5-J10,J11

5. a) Define the term *Brønsted-Lowry conjugate acid-base pair*. **(1 mark)**

a pair of chemical species which differ by only one proton

Hebden p.119

b) Give an example of a conjugate acid-base pair. **(1 mark)**

Acid: NH_4^+

Base: NH_3

J11. identify the conjugate of a given acid or base
9904-MC22-J11

22. The conjugate acid of $HAsO_4^{2-}$ is

A. H_3O^+

B. AsO_4^{3-}

C. H_3AsO_4

D. $H_2AsO_4^-$

J12. show that in any Brönsted-Lowry acid-base equation there are two conjugate pairs present
9806-MC22-J12

22. The number of conjugate pairs in a Brönsted-Lowry acid-base equation is

A. 1
B. 2
C. 3
D. 4

Strong and Weak Acids and Bases

K1. relate electrical conductivity in a solution to the concentration of ions
9901-MC23-K1

23. The solution with the lowest electrical conductivity is

A. 0.10 M H_2S even weaker acid
B. 0.10 M HNO_2 weak acid
C. 0.10 M H_2SO_3 strong acid
D. 0.10 M NH_4Cl salt
100% dissociate

K2. classify an acid or base in solution as either weak or strong by comparing conductivity
0108-MC23-K2

23. Which of the following would be the same when comparing equal volumes of 1.0 M HBr and 1.0 M CH_3COOH?
strong acid weak acid

A. the pH
B. the electrical conductivity
C. the titration curve for reaction with a base
D. the moles of base required for neutralization

Good Question!

K3. define a *strong acid* and a *strong base*
9804-MC22-K3

22. The strength of an acid depends upon its

A. E°
B. pH ← result of
C. concentration.
D. degree of ionization. better answer.

K4. define a *weak acid* and a *weak base*
0101-MC24-K4

24. Which of the following statements applies to 1.0 M $NH_{3(aq)}$ but not to 1.0 M $NaOH_{(aq)}$? **(1 mark)**

A. partially ionizes
B. neutralizes an acid
C. has a pH greater than 7
D. turns bromcresol green from yellow to blue

K5. write equations to show what happens when strong and weak acids and bases are dissolved in water (dissociation, ionization)
9908-MC24-K5
24. An equation representing the reaction of a weak acid with water is

A. $HCl + H_2O \rightarrow H_3O^+ + Cl^-$

B. $NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$

C. $HCO_3^- + H_2O \rightleftarrows H_2CO_3 + OH^-$

D. $HCOOH + H_2O \rightleftarrows H_3O^+ + HCOO^-$

K6. compare the relative strengths of acids or bases by using a table of relative acid strengths
9806-MC23-K6
23. Which of the following is a stronger base than HPO_4^{2-}?

A. H_2O
B. NO_2^-
C. CO_3^{2-}
D. $H_2PO_4^-$

K7. identify and explain why the strongest acid in aqueous solutions is H_3O^+ and the strongest base in aqueous solutions is OH^-
9801-MC23-K7
23. The strongest acid that can exist in an aqueous solution is

A. NH_2^-
B. H_3O^+ pure hydrated protons!
C. HNO_2
D. $HClO_4$

K8. predict whether products or reactants are favoured in an acid-base equilibrium by comparing the strength of the two acids (or two bases)
9804-MC24-K8
24. Consider the following equilibrium:

$$HX^- + HZ^- \rightleftarrows H_2X + Z^{2-}$$

The reactants are favoured. The strongest acid is

proton donor ∴ H_2X

A. Z^{2-}
B. HZ^-
C. HX^-
D. H_2X

K9. compare the relative concentrations of H_3O^+ (or OH^-) between two acids (or between two bases) using their relative positions on an acid strength table
0006-MC25-K9

25. Which of the following 1.0 M solutions will have the lowest $[H_3O^+]$?

A. H_2S
B. HNO_2
C. H_2CO_3
D. CH_3COOH

↳ i.e strongest base! or weakest acid!

K10. define *amphiprotic*
0001-W7-K10,K11

7. Define the term *amphiprotic*. Give an example of an ion which is amphiprotic. **(2 marks)**

Definition: a substance which can act as either an acid or a base, apart from water, amphiprotic substances start with H and have Ove charge

Example: ~~water~~, $H_2PO_4^-$, HCO_3^-

K11. identify chemical species that are amphiprotic
9808-MC24-K11

24. Which of the following are amphiprotic in aqueous solution?

I	HBr
II	H_2O ✓
III	HCO_3^- ✓
IV	$H_2C_6H_5O_7^-$ ✓

A. I and II only
B. III and IV only
C. II, III and IV only
D. I, II, III and IV

K12. describe situations in which H 2 O would act as an acid or base
~~0004-MC25-K12~~

25. Water acts as an acid when it reacts with which of the following? In other words, which is a stronger base than H_2O?

I.	CN^- ✓
II.	NH_3 ✓
III.	$HClO_4$ x (stronger acid)
IV.	CH_3COO^- ✓

e.g. $H_2O + CN^- \rightleftharpoons OH^- + HCN$
acid base

A. I and IV only
B. II and III only
C. I, II and IV only
D. II, III and IV only

K_w, *pH, and pOH*

L1. write equations representing the ionization of water using either H_3O^+ and OH^- or H^+ and OH^-
0008-MC25-L1

25. Which of the following represents the ionization of water?

A. $H_2O \rightleftarrows H_2 + \frac{1}{2}O_2$

B. $2H_2O \rightleftarrows H_3O^+ + OH^-$

C. $2H_2O + O_2 \rightleftarrows 2H_2O_2$

D. $H_2O \rightleftarrows \frac{1}{2}O_2 + 2H^+ + 2e^-$

L2. write the equilibrium expression for the ion product constant of water, K_w
9806-MC25-L2

25. The equilibrium expression for the ion product constant of water is

A. $K_w = [H_3O^+][OH^-]$

B. $K_w = \dfrac{1}{[H_3O^+][OH^-]}$

C. $K_w = \dfrac{[H_2O]^2}{[H_3O^+][OH^-]}$

D. $K_w = \dfrac{[H_3O^+][OH^-]}{[H_2O]^2}$

L3. predict the effect of the addition of an acid or base to the equilibrium system:

$$2\,H_2O(l) \leftrightarrows H_3O^+\,(aq) + OH^-\,(aq)$$

9906-MC26-L3

26. Addition of HCl to water causes

A. both $[H_3O^+]$ and $[OH^-]$ to increase.

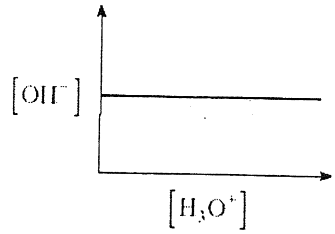
B. both $[H_3O^+]$ and $[OH^-]$ to decrease.

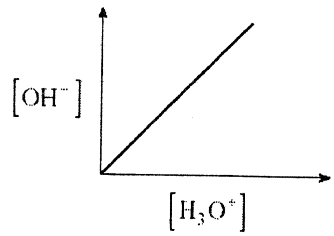
C. $[H_3O^+]$ to increase and $[OH^-]$ to decrease.

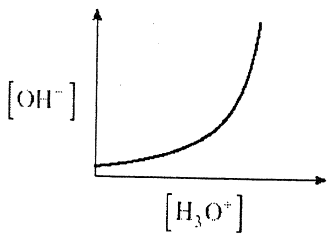
D. $[H_3O^+]$ to decrease and $[OH^-]$ to increase.

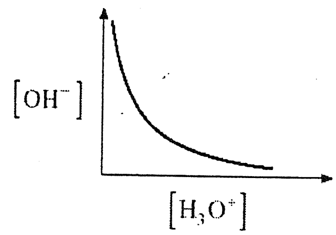
L4. state the relative concentrations of H_3O^+ and OH^- in acid, base, and neutral solutions
9906-MC27-L4

27. Which of the following graphs describes the relationship between $[H_3O^+]$ and $[OH^-]$ in aqueous solutions at a constant temperature?

A.


B.


C.


D.


inverse log relationship

L5. state the value of K_w at 25°C
9808-MC25-L5
25. What is the value of K_w at 25°C?

✓ A. 1.0×10^{-14}
B. 1.0×10^{-7}
C. 7
D. 14

L6. describe the variation of the value of K_w with temperature
9806-MC27-L6
27. Consider the following equilibrium:

$$2H_2O_{(\ell)} + \text{energy} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$$

When the temperature of water is changed, the pH decreases. Which of the following explains this pH change?

∴ $[H^+]\uparrow$ ∴ shifts right ∴ $K_w\uparrow$
∴ the $\uparrow$ (NRG$\uparrow$)

✓ A. Temperature and K_w both increase.
B. Temperature and K_w both decrease.
C. Temperature increases and K_w decreases.
D. Temperature decreases and K_w increases.

L7. calculate the concentration of H_3O^+ (or OH^-) given the other, using K_w
9801-MC26-L7
26. The $[H_3O^+]$ in 100.0 mL of 0.015 M KOH is

$\frac{10^{-14}}{.015}$

✓ A. 6.7×10^{-13}
B. 6.7×10^{-12}
C. 1.5×10^{-3}
D. 1.5×10^{-2}

L8. describe the pH scale with reference to everyday solutions
No Examples Found!

L9. define *pH* and *pOH*
9804-MC27-L9

27. The relationship between pOH and $[OH^-]$ is

A. $-\log pOH = [OH^-]$
B. $pOH = -\log[OH^-]$
C. antilog $pOH = [OH^-]$
D. $pOH = \text{antilog}(-[OH^-])$

L10. define pK_w, give its value at 25°C, and its relation to pH and pOH
9901-MC26-L10

26. The value of pK_w at 25°C is

A. 1.0×10^{-14}
B. 1.0×10^{-7}
C. 7.00
D. 14.00

L11. perform calculations relating pH, pOH, H_3O^+, and OH^-
9804-MC28-L11

28. The pH of a 0.025 M NaOH solution is

A. 0.94
B. 1.60
C. 12.40
D. 13.06

L12. calculate H_3O^+ or OH^- from pH and pOH
9806-MC28-L12

28. The $[H_3O^+]$ of a solution with a pOH of 4.60 is

A. 4.0×10^{-10} M
B. 2.5×10^{-5} M
C. 6.6×10^{-1} M
D. 9.7×10^{-1} M

K_a and K_b Problem Solving

M1. write *K a* and *K b* equilibrium expressions
9806-MC29-M1

29. The K_b expression for aniline, $C_6H_5NH_2$, is

$C_6H_5NH_2 + H_2O \rightleftharpoons C_6H_5NH_3^+ + OH^-$
base

A. $K_b = [C_6H_5NH_3^+][OH^-]$

B. $K_b = [C_6H_5NH^-][H_3O^+]$

✓ C. $K_b = \dfrac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}$

D. $K_b = \dfrac{[C_6H_5NH^-][H_3O^+]}{[C_6H_5NH_2]}$

M2. relate the magnitude of *Ka* or *Kb* to the strength of the acid or base
9804-MC29-M2

29. Which is the weakest of the following acids?

✓ A. HCN i.e lowest on list
B. NH_4^+
C. HNO_2
D. HNO_3

M3. given the *Ka*, *Kb*, and initial concentration, calculate any of the following: H_3O^+, OH^-, pH and pOH
9901-W5-M3

5. Calculate the pH of 0.50 M H_3BO_3. **(4 marks)**

$K_a = 7.3 \times 10^{-10} = \dfrac{[H^+][H_2BO_3^-]}{[H_3BO_3]} = \dfrac{x^2}{0.50 - x}$

H_3BO_3	$\rightleftharpoons$	H^+	+	$H_2BO_3^-$
0.50		0		0
$-x$		$+x$		$+x$
$0.50 - x$		x		x

✓ ice table = 1½ marks

1½ marks

Assume $x \ll 0.50$
$\therefore x^2 = 1.91 \times 10^{-5}$

$\therefore pH = 4.72$

1 mark

M4. calculate the value of *Kb* for a base given the value of *Ka* for its conjugate acid (or vice versa)
9801-MC29-M4

29. The value of K_b for HPO_4^{2-} is

acting as a base

Find Ka in table ; $K_b = \dfrac{K_w}{K_a}$

accepting a H^+ acting as base

A. 2.2×10^{-13}
B. 6.2×10^{-8}
C. 1.6×10^{-7}
No! → D. 4.5×10^{-2}

$K_a = 2.2 \times 10^{-13}$

yes ① $H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$ K_a ?

no! ② $HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$ K_a ?

M5. calculate the value of Ka or Kb given the pH and initial concentration
9808-W6-M5
6. A 3.50×10^{-3} M sample of the unknown acid, HA, has a pH of 2.90. **(4 marks)**
Calculate the value of K_a and identify this acid. ice table!

pH = 2.90 ∴ $[H^+] = 1.259 \times 10^{-3}$

	HA	⇌	H^+	+	A^-
I	3.50×10^{-3}		0		0
C	$~~1.259~~ \times 10^{-3}$		+x		+x
E	$3.50 \times 10^{-3} - 1.259 \times 10^{-3}$		1.259×10^{-3}		1.259×10^{-3}

ice table = 2 marks

$$K_a = \frac{[H^+][A^-]}{[HA]}$$ 1½ marks

$K_a = 7.07 \times 10^{-4}$ ½ mark

Ka citric acid = 2.1×10^{-4} ∴ probably citric acid

Hydrolysis of Salts
N1. write a dissociation equation for a salt in water
0006-W7-N1,N2,N3
7. Consider the salt ammonium acetate, NH_4CH_3COO.

a) Write the equation for the dissociation of NH_4CH_3COO. **(1 mark)**

$NH_4CH_3COO(s) \rightleftharpoons NH_4^+(aq) + CH_3COO^-(aq)$

solid salt

b) Write equations for the hydrolysis reactions which occur. **(2 marks)**

$K_a = 5.6 \times 10^{-10}$ $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3^+(aq) + H_3O^+(aq)$

$K_b = \frac{10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}$ $CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$

c) Explain why a solution of NH_4CH_3COO has a pH = 7.00. **(2 marks)**
Support your answer with calculations.

Ka for NH_4^+ = Kb for CH_3COO^- = 5.6×10^{-10}

∴ equal opposition; balanced ∴ neutral pH = 7.00

from Provincial key → "the acidic cation is completely neutralized by ..."

N2. write net ionic equations representing the hydrolysis of salts
9904-MC29-N2

29. The net ionic equation for the hydrolysis of NH_4ClO_4 is

conjugate of a strong acid ∴ neutral
weak acid ∴ undergoes hydrolysis

A. $NH_4ClO_{4(s)} \rightleftarrows NH_4^+{}_{(aq)} + ClO_4^-{}_{(aq)}$

✓ B. $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftarrows NH_{3(aq)} + H_3O^+{}_{(aq)}$

C. $ClO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows HClO_{4(aq)} + OH^-{}_{(aq)}$

D. $NH_4^+{}_{(aq)} + ClO_4^-{}_{(aq)} \rightleftarrows NH_{3(aq)} + HClO_{4(aq)}$

N3. predict qualitatively whether a salt solution would be acidic, basic, or neutral
9801-MC30-N3

30. Which of the following 0.10 M solutions is basic?

A. LiCl ✗
✓ B. K_3PO_4 ✓ ← conjugate of weak acid is PO_4^{3-} ← undergoes base hydrolysis
C. $NaClO_4$ ✗
D. NH_4NO_3 → would be acidic

N4. determine whether an amphiprotic ion will act as a base or an acid in solution
9804-MC30-N4

30. A solution of 0.10 M HSO_3^- will be

A. basic because $K_a < K_b$
B. acidic because $K_a < K_b$
✓ C. acidic because $K_a > K_b$
D. neutral because $K_a = K_b$

Be careful.
$K_a: 1.0 \times 10^{-7}$
but HSO_3^- is amphiprotic ∴ there will also be a K_b
i.e. $H_2SO_3 \rightleftarrows H^+ + HSO_3^-$ $K_a = 1.5 \times 10^{-2}$
$K_b = \dots$
$K_a > K_b$ ∴ will be acidic

Indicators

O1. describe an indicator as a mixture of a weak acid and its conjugate base, each with distinguishing colours
9908-MC31-O1

31. Consider the following equilibrium for an indicator:

$$HInd + H_2O \rightleftarrows H_3O^+ + Ind^-$$

Which two species must be of two different colours in order to be used as an indicator?

A. HInd and H_2O
✓ B. HInd and Ind^-
C. H_3O^+ and Ind^-
D. HInd and H_3O^+

O2. describe the term *transition point* of an indicator, including the conditions that exist in the equilibrium system
9804-MC31-O2

31. Consider the following equilibrium for the indicator phenol red:

$$HInd + H_2O \rightleftarrows Ind^- + H_3O^+$$

In a solution with a pH of 7.3, the indicator phenol red is

Use chart
Phenol Red 6.6 – 8.0
yellow to red

A. red because $[HInd] < [Ind^-]$
B. red because $[HInd] = [Ind^-]$
C. yellow because $[HInd] > [Ind^-]$
D. orange because $[HInd] = [Ind^-]$ ✓

∴ pKa = pH mix

O3. describe the shift in equilibrium and resulting colour changes as an acid or a base is added to an indicator
9801-MC31-O3

31. Consider the following equilibrium for the indicator HInd at its transition point:

$$HInd + H_2O \rightleftarrows Ind^- + H_3O^+ \downarrow$$

When a small amount of base is added, the equilibrium shifts to the — Le Chatelier

A. left and the $[HInd] > [Ind^-]$
B. left and the $[HInd] < [Ind^-]$
C. right and the $[HInd] > [Ind^-]$
D. right and the $[HInd] < [Ind^-]$ ✓

O4. predict the approximate pH at the transition point using the *K*a value of an indicator
9804-MC32-O4

32. The indicator with $K_a = 4 \times 10^{-8}$ is — pH = pKa for transition point of indicator

→ −log = 7.40

A. orange IV.
B. neutral red. ✓
C. thymol blue.
D. phenolphthalein.

find ½ way pt in table

O5. predict the approximate *K*a value for an indicator given the approximate pH range of the colour change
9801-MC32-O5

32. The approximate K_a value for the indicator thymolphthalein is

→ Again, ½ way point → Range is 9.4 – 10.6

A. 1×10^{-10} ✓
B. 1×10^{-4}
C. 4
D. 10

(10)

∴ Ka = 1.0×10^{-10}

Neutralizations of Acids and Bases & Titration Curves

P1. demonstrate an ability to design and perform a neutralization experiment involving the following:
- primary standards
- standardized solutions
- titration curves

- indicators selected so the end point coincides with the equivalence point

9908-MC32-P1

32. Which of the following indicators is yellow at a pH of 10.0?

A. methyl red
B. phenol red No
C. thymol blue No
D. methyl violet No

P2. calculate from titration data the concentration of an acid or base

9804-MC33-P2

33. A 25.0 mL sample of H_2SO_4 requires 25.0 mL of 0.100 M KOH for complete neutralization. The initial concentration of the H_2SO_4 is

Be careful of equivalents!
$[H_2SO_4] = \frac{1}{2} \times [KOH]$!

A. 5.00×10^{-2} M
No! B. 1.00×10^{-1} M
C. 2.00×10^{-1} M
D. 4.00×10^{-1} M

P3. calculate the volume of an acid or base of known molarity needed to neutralize a known volume of a known molarity base or acid

9801-MC33-P3

33. What volume of 0.100 M NaOH is needed to completely neutralize 25.0 mL of 0.100 M H_2SO_4?

2x as much Same type of question!

A. 12.5 mL
B. 25.0 mL
C. 50.0 mL
D. 75.0 mL

P4. write formula, complete ionic, and net ionic neutralization equations for:
- a strong acid by a strong base
- a weak acid by a strong base
- a strong acid by a weak base

9806-MC34-P4

34. The net ionic equation for the reaction between $KOH_{(aq)}$ and $HBr_{(aq)}$ is

write is out first
$\cancel{K^+} + OH^- + H^+ + \cancel{Br^-} \rightarrow H_2O + \cancel{K^+} + \cancel{Br^-}$
K^+, Br^- spectator ions!

A. $K^+_{(aq)} + Br^-_{(aq)} \rightarrow KBr_{(s)}$
B. $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(\ell)}$
No! C. $KOH_{(aq)} + HBr_{(aq)} \rightarrow KBr_{(aq)} + H_2O_{(\ell)}$
D. $K^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + Br^-_{(aq)} \rightarrow K^+_{(aq)} + Br^-_{(aq)} + H_2O_{(\ell)}$

P5. calculate the pH of a solution formed when a strong acid is mixed with a strong base

9801-MC34-P5

34. When 0.10 mol of NaOH is added to 1.00 L of 0.30 M HCl, the pH of the resulting solution is

A. 0.52
B. 0.70
C. 1.00
D. 13.30

$NaOH + HCl \rightarrow H_2O + NaCl$
0.10 0.30

∴ have 0.20 mol H^+ left in 1.00 L
∴ $[H^+] = 0.2$ M
∴ pH = 0.70

P6. contrast the equivalence point (stoichiometric point) of a strong acid-strong base titration with the equivalence point of a titration involving a weak acid-strong base or strong acid-weak base
9806-MC33-P6

33. When a 1.0 M acidic solution is titrated with a 1.0 M basic solution, the pH at the equivalence point is 8.5. The reactants could be

pH >8.5 ∴ titrating a weak acid with strong base

A. HBr and KOH
B. HNO_3 and NH_3
C. HCl and NaOH
D. HNO_2 and NaOH
wa. strong base

Buffer Solutions

Q1. describe the tendency of buffer solutions to resist changes in pH
9906-MC35-Q1

35. Consider the following:

I.	H_3O^+
II.	CH_3COO^-
III.	CH_3COOH

conjugate base of weak acid
weak acid

The purpose of a buffer system consisting of CH_3COOH and CH_3COONa is to maintain a relatively constant concentration of

Constant pH i.e. $[H^+]$

A. I only.
B. I and II only.
C. II and III only.
D. I, II and III.

Q2. describe the composition of an acidic buffer and a basic buffer
9804-MC35-Q2

35. A buffer solution can be prepared by combining, in water, equal moles of

identify which is the weak acid

A. HF and KF
B. HIO_3 and HI
C. HBr and LiBr
D. $HClO_4$ and NaOH

Q3. outline a procedure to prepare a buffer solution
9801-MC35-Q3

35. Which of the following could be used to form a buffer solution?

A. HBr and NaOH
B. HCl and NH_4Cl
C. HNO_3 and $NaNO_3$
D. H_2CO_3 and $NaHCO_3$

Q4. identify the limitations in buffering action
No Examples Found!

$\frac{1}{10}$ or $\frac{10}{1}$

Q5. describe qualitatively how the buffer equilibrium shifts as small quantities of acid or base are added to the buffer

9806-MC35-Q5
35. Consider the following equilibrium for a buffer solution:

$$CH_3COOH + H_2O \rightleftarrows CH_3COO^- + H_3O^+$$

∴ $[CH_3COO^-]\downarrow$

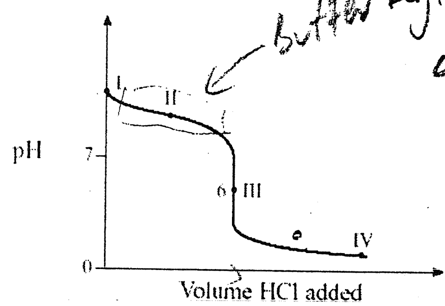
When a small amount of acid is added to this system, and equilibrium is reestablished,

A. $[CH_3COO^-]$ and pH have both increased.
B. $[CH_3COOH]$ and pH have both decreased.
C. $[CH_3COO^-]$ has decreased and pH remains relatively constant.
D. $[CH_3COOH]$ has decreased and pH remains relatively constant.

Q6. describe common buffer systems present in industrial, environmental, or biological systems
9908-MC35-Q6
35. Consider the following graph for the titration of 0.1M NH_3 with 0.1M HCl:

buffer region – add lots of acid/base with little change in pH.
← weak base vs strong acid

*



A buffer solution is present at point

A. I
B. II
C. III
D. IV

Acid Rain

R1. write equations representing the formation of acidic solutions or basic solutions from non-metal and metal oxides
9804-MC36-R1
36. Which of the following oxides will dissolve in water to form an acidic solution?

A. SO_2
B. TiO
C. K_2O
D. MgO

R2. describe the pH conditions required for rain to be called acid rain
9808-MC36-R2
36. Which of the following could be the pH of a sample of acid rain?

A. 0
B. 4
C. 7
D. 10

R3. relate the pH of normal rain water to the presence of dissolved CO 2
9801-MC36-R3

36. Normal rain has a pH of approximately 6 as a result of dissolved

A. oxygen.
B. carbon dioxide.
C. sulphur dioxide.
D. nitrogen dioxide.

R4. describe sources of NO x and SO x
0001-MC37-R4

37. A gas which is produced by internal combustion engines and contributes to the formation of acid rain is

A. H_2
B. O_3
C. CH_4
D. NO_2

R5. discuss general environmental problems associated with acid rain
No Examples Found!

End of Chemistry 12 – Unit 4: Acids, Bases, and Salts Section

KEY

5. OXIDATION-REDUCTION

Introduction

S1. define and apply the following: *oxidation; reduction; oxidizing agent; reducing agent; half-reaction; redox reaction*

9804-MC38-S1

38. When ClO_3^- is oxidized, a possible product is

A. Cl^-
B. ClO^-
C. ClO_2^-
D. ClO_4^-

S2. determine the following:
- the oxidation number of an atom in a chemical species
- the change in oxidation number an atom undergoes when it is oxidized or reduced
- whether an atom has been oxidized or reduced by its change in oxidation number

9801-MC37-S2

37. Which of the following represents a redox reaction?

A. $H_2CO_3 \rightarrow H_2O + CO_2$
B. $CuS + H_2 \rightarrow H_2S + Cu$
C. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$
D. $2HCl + Na_2SO_3 \rightarrow 2NaCl + H_2O + SO_2$

S3. relate change in oxidation number to gain or loss of electrons

9904-MC39-S3

39. Consider the following:

$$\overset{+4}{NO_2} \rightarrow \overset{+3}{N_2O_3}$$

$H_2O + 2NO_2 \rightarrow N_2O_3 + 2H^+ + 2e^-$

(Balance it first!)

$\therefore 1\ NO_2 : 1e^-$

The nitrogen atom in each NO_2

A. loses one electron.
B. gains one electron.
C. loses two electrons.
D. gains two electrons.

S4. from data for a series of simple redox reactions, create a simple table of reduction half-reactions

9808-MC41-S4

41. In an experiment to determine the relative strength of oxidizing agents, three metals, Ag, Ru and Pd were placed into solutions containing a cation of the other two metals. The results were recorded in the following data table:

Look at solutions (since contain...

SOLUTION / METAL	Pd^{2+}	Ru^{2+}	Ag^+
Ag	reaction	no reaction	
Ru	reaction		reaction
Pd		no reaction	no reaction

The relative strength of oxidizing agents is

A. Ru > Ag > Pd
B. Pd > Ag > Ru
C. $Ru^{2+} > Ag^+ > Pd^{2+}$
D. $Pd^{2+} > Ag^+ > Ru^{2+}$

→ also! ... be reduced

S5. identify the relative strengths of oxidizing and reducing agents from their positions on a half-reaction table

9901-MC39-S5

39. Which of the following is the strongest reducing agent?

See table

A. Al

B. Cu

C. Zn

D. Mg

S6. use a table of reduction half-reactions to predict whether a spontaneous redox reaction will occur between any two species

9901-MC40-S6

40. Which of the following reactions is spontaneous at standard conditions?

to be reduced higher

A. $Pb + Cu^{2+} \rightarrow Cu + Pb^{2+}$

B. $H_2 + Mg^{2+} \rightarrow Mg + 2H^+$

C. $Br_2 + 2Cl^- \rightarrow Cl_2 + 2Br^-$

D. $2Ag + Cu^{2+} \rightarrow Cu + 2Ag^+$

Balancing Redox Equations

T1. balance a half-reaction in solution (acid, base, neutral)

9906-MC41-T1

41. Which of the following half-reactions is balanced?

A. $ClO^- + H_2O + e^- \rightarrow Cl_2 + 2OH^-$

B. $2ClO^- + H_2O + 2e^- \rightarrow Cl_2 + 3OH^-$

C. $2ClO^- + 2H_2O + 2e^- \rightarrow Cl_2 + 4OH^-$

D. $2ClO^- + 2H_2O \rightarrow Cl_2 + 4OH^- + 2e^-$

Remember

$2e^- + 4H^+ + 2ClO^- \rightarrow Cl_2 + 2H_2O$

T2. balance a net ionic redox reaction in acid and base solution

9904-MC41-T2

41. Consider the following half-reaction:

$$\underline{1}\ AsH_3 + \underline{3}\ H_2O \rightarrow \underline{\ \ }\ H_3AsO_3 + \underline{?}\ H^+ + \underline{\ \ }\ e^-$$

6

When this half-reaction equation is balanced, the coefficient for H^+ is

A. 2

B. 3

C. 6

D. 9

T3. write the equations for reduction and oxidation half-reactions given a redox reaction

9801-MC43-T3

43. Consider the redox reaction below:

$$2BrO_3^- + 10Cl^- + 12H^+ \rightarrow Br_2 + 5Cl_2 + 6H_2O$$

The oxidation half-reaction involved in this reaction is

✓ A. $2Cl^- \rightarrow Cl_2 + 2e^-$
B. $2H^+ \rightarrow H_2 + 2e^-$
C. $BrO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2}Br_2 + 3H_2O$
D. $BrO_3^- + 6H^+ \rightarrow \frac{1}{2}Br_2 + 3H_2O + 5e^-$

T4. identify reactants and products for several redox reactions performed in a laboratory and balance the equations
9804-MC43-T4

43. When H_2O_2 is added to an acidified MnO_4^- solution, a spontaneous reaction occurs in which a product of the oxidation reaction is

No need to know this - You can get it from the table

① $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
② $O_2 + 2H^+ + 2e^- \leftarrow H_2O_2$

✓ A. O_2
B. H_2O
C. Mn^{2+}
D. MnO_2

T5. select a suitable reagent to be used in a redox titration in order to determine the concentration of a species
9804-MC44-T5

44. To determine the $[Cr_2O_7^{2-}]$ in a redox titration, a suitable reagent is

Look in table to see ...

A. Ni^{2+} Ni
✓ B. Sn^{2+}
C. Zn^{2+}
D. Mg^{2+}

T6. determine the concentration of a species by performing a redox titration
9806-MC42-T6

42. Consider the following:

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 5O_2 + 2Mn^{2+} + 8H_2O$$

In an experiment, 2.00×10^{-4} mol of MnO_4^- is required to titrate 10.0 mL of H_2O_2 to the equivalence point. The concentration of H_2O_2 is

mol H_2O_2 = 2.00×10^{-4} mol × 5/2
÷ by .01 L
= ... M

A. 5.00×10^{-3} M
B. 8.00×10^{-3} M
C. 2.00×10^{-2} M
✓ D. 5.00×10^{-2} M

Electrochemical Cells

U1. define, construct, and label the parts of an electrochemical cell
0001-MC43-U1

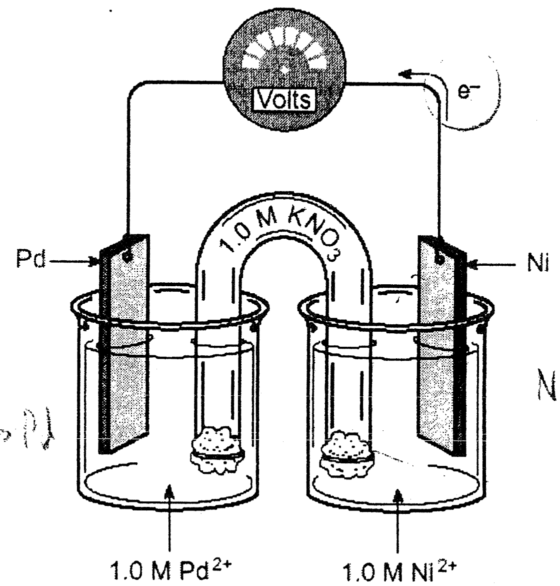
43. In an operating electrochemical cell the function of a salt bridge is to

A. allow hydrolysis to occur.
B. allow a non-spontaneous reaction to occur.
C. permit the migration of ions within the cell.
D. transfer electrons from the cathode to the anode.

U2. identify the half-reactions that take place at each electrode
9801-MC44-U2

Use the following diagram to answer questions 44, 45 and 46.

Red.
$Pd^{2+} + 2e^- \rightarrow Pd$



Ox.
$Ni \rightarrow Ni^{2+} + 2e$

44. As the cell operates, the electrons flow from the nickel electrode to the palladium electrode. The reaction occurring at the anode is

An Ox

A. $Pd \rightarrow Pd^{2+} + 2e^-$
B. $Ni \rightarrow Ni^{2+} + 2e^-$
C. $Pd^{2+} + 2e^- \rightarrow Pd$
D. $Ni^{2+} + 2e^- \rightarrow Ni$

ox. rxn

U3. predict the direction of movement of each type of ion in the cell
9801-MC45-U3 (Use diagram from previous question!)

45. As the cell operates,

A. both the K^+ and the NO_3^- migrate into the nickel half-cell.
B. both the K^+ and the NO_3^- migrate into the palladium half-cell.
C. the K^+ migrates into the nickel half-cell and the NO_3^- migrates into the palladium half-cell.
D. the K^+ migrates into the palladium half-cell and the NO_3^- migrates into the nickel half-cell.

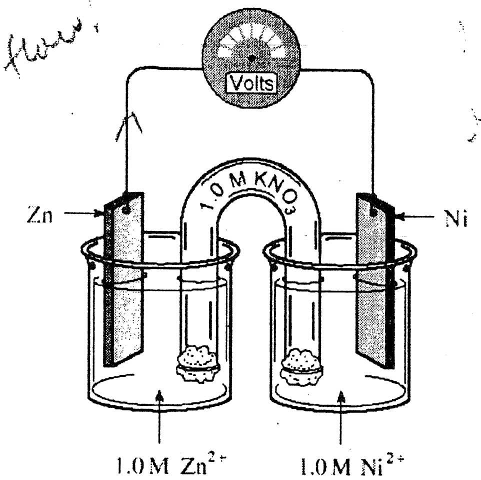
U4. predict the direction of flow of electrons in an external circuit
0004-MC45-U4,U5

45. Consider the following electrochemical cell:

From Table

$Ni^{2+} + 2e^- \rightarrow Ni(s)$

$Zn(s) \rightarrow$



Which of the following occurs as the cell operates?

A. Zinc electrode is reduced and increases in mass.
B. Zinc electrode is reduced and decreases in mass.
C. Zinc electrode is oxidized and increases in mass.
D. Zinc electrode is oxidized and decreases in mass.

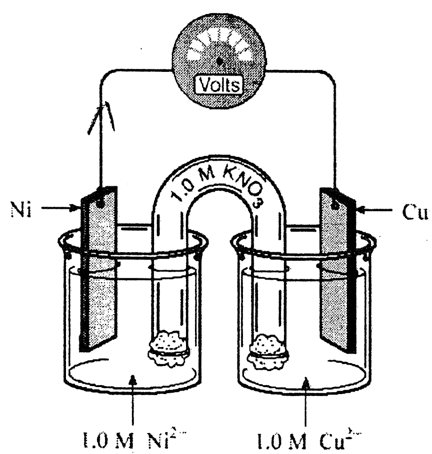
U5. predict which electrode will increase in mass and which will decrease in mass as the cell operates
0008-MC45-U5

Use the following diagram to answer questions 45 and 46.

From table

$Cu^{2+} + 2e^- \rightarrow Cu$

$Ni(s) \rightarrow Ni^{2+} + 2e^-$

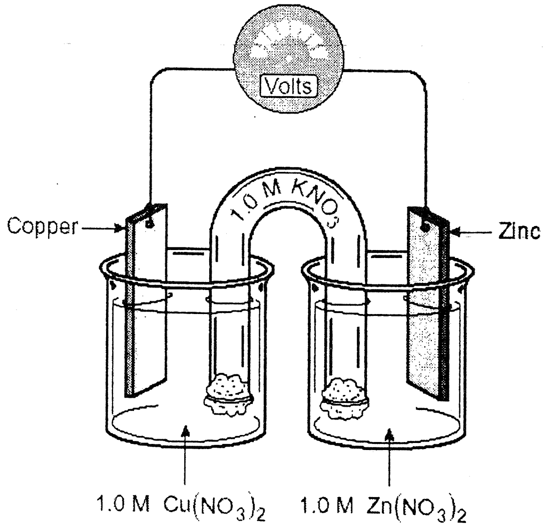


$Ni | Ni^{2+} || Cu | Cu^{2+}$

45. As the cell operates, observations include

	Mass of Nickel Electrode	Concentration of Copper Ions
A.	decreases	increases
B.	decreases	decreases
C.	increases	increases
D.	increases	decreases

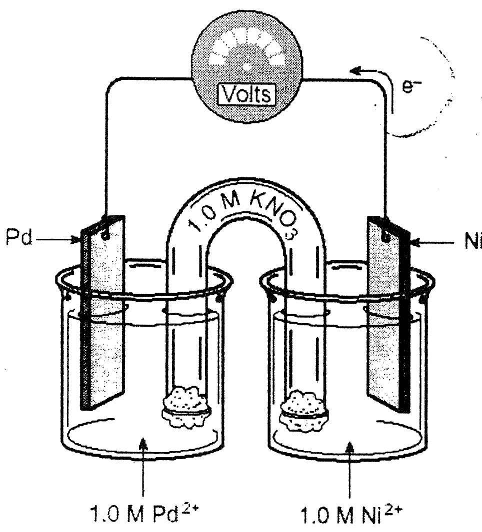
U6. predict the voltage of the cell when equilibrium is reached
9908-MC43-U6
Use the following diagram to answer questions 42 and 43.



43. At equilibrium, the voltage of the cell above is

A. −1.10 V
B. 0.00 V
C. +0.42 V
D. +1.10 V

U7. assign voltages to the reduction half-reactions of oxidizing agents by comparison of several cells
9801-MC46-U7
Use the following diagram to answer questions 44, 45 and 46.



i.e. Ni →

46. The initial cell voltage is 1.21 V. The reduction potential of Pd^{2+} is

A. −1.21 V
B. −0.95 V
C. +0.95 V
D. +1.21 V

1.21 V

U8. describe the significance of the *E*° of an electrochemical cell
9901-MC44-U8

44. Which of the following affects the potentials of electrochemical cells?

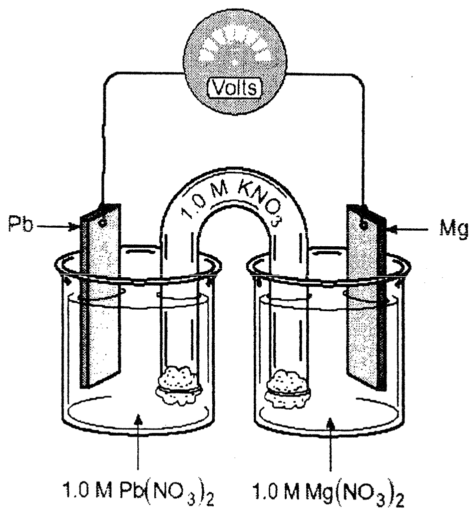
I.	species used as oxidizing agent
II.	temperature
III.	concentration of reactants

SA: P + [ ]

A. I and II only.
B. II and III only.
C. I and III only.
D. I, II and III.

U9. predict the voltage (*E*°) of an electrochemical cell using the table of standard reduction half-cells
9808-MC44-U9

Use the following diagram to answer questions 43, 44 and 45.



Pb^{2+} reduction

$Pb^{2+} + 2e^- \rightarrow Pb$ -0.13

$Mg \rightarrow Mg^{2+}$ $+2.37$

44. The E° of the cell above is

A. −2.50 V
B. −2.24 V
C. +2.24 V
D. +2.50 V

U10. predict the spontaneity of the forward or reverse reaction from the *E*° of a redox reaction
9804-MC42-U10

42. Consider the following redox reaction:

$$2Fe^{2+} + MnO_2 + 4H^+ \rightleftarrows 2Fe^{3+} + Mn^{2+} + 2H_2O$$

The forward reaction has a

A. positive E° value and is spontaneous.
B. negative E° value and is spontaneous.
C. positive E° value and is nonspontaneous.
D. negative E° value and is nonspontaneous.

oxid. $Fe^{2+} \rightarrow Fe^{3+} + 1e^-$

red. $MnO_2 \rightarrow Mn$

+0.45

U11. describe how electrochemical concepts can be used in various practical applications
9806-MC43-U11

43. A lead storage battery contains electrochemical cells which involve the following half-reactions:

$$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightleftarrows PbSO_4 + 2H_2O \qquad E^\circ = +1.69\ V$$

$$PbSO_4 + 2e^- \rightleftarrows Pb + SO_4^{2-} \qquad E^\circ = -0.36\ V$$

Use the data above to calculate the E° for one of these cells.

$+1.69$
$+0.36$
$+2.05$

A. $E^\circ = +1.33$ V
B. $E^\circ = -1.33$ V
C. $E^\circ = -2.05$ V
D. $E^\circ = +2.05$ V

Corrosion

V1. describe the conditions necessary for corrosion to occur
9801-MC47-V1

47. Consider the following chemicals:

I	water
II	oxygen gas
III	nitrogen gas

At 25°C, a piece of iron rusts in the presence of

A. I only.
B. III only.
C. I and II only.
D. II and III only.

V2. analyse the process of metal corrosion in electrochemical terms
9901-MC45-V2

45. In the rusting of iron, the reduction reaction that occurs is

A. $Fe \rightarrow Fe^{2+} + 2e^-$
B. $Fe^{2+} + 2e^- \rightarrow Fe$
C. $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
D. $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

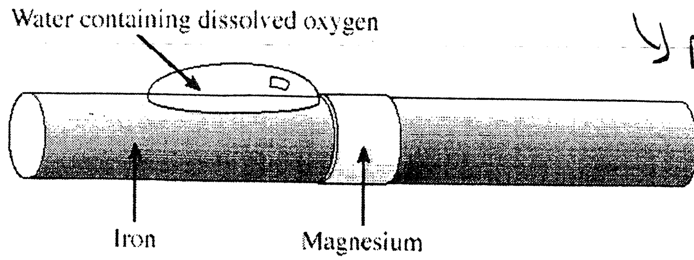
V3. suggest several methods of preventing or inhibiting corrosion of a metal
9901-MC46-V3

46. During a cathodic protection, the sacrificial anode

A. accepts electrons from the protected metal.
B. reacts spontaneously with the protected metal.
C. oxidizes more readily than the protected metal.
D. causes the protected metal to become an anode.

V4. describe and explain the principle of cathodic protection
0006-MC47-V4
47. Consider the following diagram of a piece of iron, cathodically protected by magnesium:

↳ reverse of normal rusting!



An Ox Cored.

What is happening during this process?

A. Iron acts as the anode and water is oxidized.
B. Iron acts as the cathode and oxygen is reduced. ✓
C. Magnesium acts as the anode and iron is oxidized.
D. Magnesium acts as the cathode and iron is reduced.

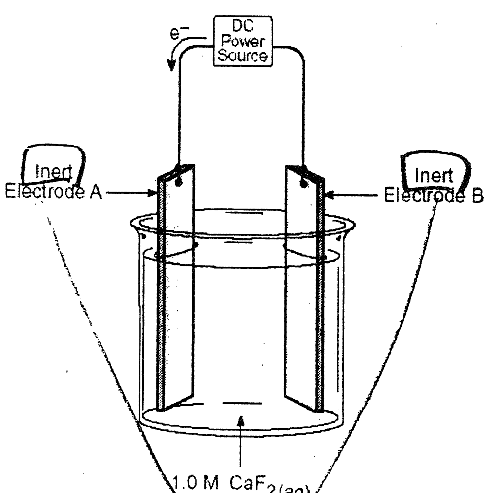
Magnesium is oxidized instead

Electrolytic Cells

W1. define *electrolysis* and *electrolytic cell*
9906-MC48-W1
48. In order for an electrolytic cell to operate, it must have

A. a voltmeter.
B. a salt bridge.
C. a power supply. ✓
D. an aqueous solution.

W2. design and label the parts of an electrolytic cell capable of electrolysing an aqueous salt (use of overpotential effect not required)
9806-MC48-W2
Use the following diagram to answer questions 47 and 48.



48. In the electrolytic cell above, a suitable substance for Electrode B is

A. carbon.
B. lithium.
C. sodium.
D. calcium.

Carbon is inert (like N_2)

W3. predict the direction of flow of all ions in the cell
9908-MC47-W3

47. What substances are formed at the anode and cathode during electrolysis of molten sodium chloride, $NaCl_{(l)}$?

	ANODE	CATHODE	
A.	O_2	H_2	
B.	Na	Cl_2	or
C.	Cl_2	H_2	
✓ D.	Cl_2	Na	

$Na^+ + 1e^- \rightarrow Na$ red.
An ox Cared
∴ not B
∴ D

W4. write the half-reaction occurring at each electrode
9801-MC48-W4

48. During the electrolysis of 1.0 M Na_2SO_4, the reaction at the cathode is

A or D but "D" is higher reduction

A. $Na^+ + e^- \rightarrow Na$
B. $2SO_4^{2-} \rightarrow S_2O_8^{2-} + 2e^-$ or (both reductions)
C. $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
✓ D. $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

→ An ox Cared ∴ a reduction but highest one.

← See Hebden p. 238 "During the electrolysis of Aqueous Solutions, you must always consider the possibility that H_2O may oxidize and/or reduce!"

W5. demonstrate the principles involved in simple electroplating
9901-MC48-W5

48. When electroplating an iron medallion with nickel,

A. the medallion is an anode. ✗
B. the cathode is pure nickel. ✗
✓ C. the solution contains Ni^{2+}.
D. the anode reaction is $Ni^{2+} + 2e^- \rightarrow Ni$ ✗

reduction adds metal
CARED.

W6. construct an electrolytic cell capable of electroplating an object
9904-MC47-W6

47. Why can an object **not** be plated with magnesium using 1.0 M MgI_2?

A. Water is a stronger reducing agent than I^-
B. Water is a stronger oxidizing agent than I^-
C. Water is a stronger reducing agent than Mg^{2+}
D. Water is a stronger oxidizing agent than Mg^{2+}

W7. describe the electrolytic aspects of metal refining processes
9908-MC48-W7

48. What is the minimum voltage required to form nickel from an aqueous solution of NiI_2 using inert electrodes?

A. 0.26 V
B. 0.28 V
C. 0.54 V
D. 0.80 V

W8. draw and label the parts of an electrolytic cell used for electrolysis of a molten binary salt
0006-W10-W8

10. Draw and label an electrochemical cell using a copper anode and having an E° value > 1.00 V.
(2 marks)

End of Chemistry 12 – Unit 5: Oxidation-Reduction Section