Chemistry 30 | Released Items

2017 Released Diploma Examination Items

Alberta Government

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Contents

Introduction

The questions presented in this booklet are from the August 2016 Chemistry 30 Diploma Examination. This material, along with the *Program of Studies*, the *Chemistry 30 Information Bulletin*, and the *Student-based Performance Standards*, can provide insights that assist you with decisions relative to instructional programming.

These examination items are released in both English and French by the Assessment Sector.

Alberta Education, Provincial Assessment Sector   1   Mathematics 30–1

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Chemistry 30 Diploma Examination August 2016 Key

Question	Key	Question	Key
MC1	B	MC23	D
MC2	B	MC24	A
NR1	6342	MC25	B
MC3	A	NR9	2368 any order
MC4	D	MC26	D
MC5	A	MC27	C
MC6	D	NR10	2356 any order
NR2	2542	MC28	B
MC7	B	MC29	A
MC8	D	MC30	B
MC9	A	NR11	3124
NR3	2413, 2431, 4213, 4231	MC31	B
MC10	A	MC32	C
MC11	B	MC33	C
MC12	C	NR12	1.96
MC13	D	MC34	A
MC14	D	MC35	D
MC15	C	MC36	A
NR4	1131	NR13	1356, 1536
MC16	D	MC37	D
NR5	2413, 2431, 4213, 4231	MC38	C
NR6	336	NR14	1811
NR7	1.52	NR15	2311
MC17	C	MC39	B
MC18	A	MC40	B
MC19	C	NR16	2.68
NR8	21.5	MC41	A
MC20	A	MC42	D
MC21	B	MC43	C
MC22	C	MC44	C

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Chemistry 30 Diploma Examination August 2016 Multiple-choice and Numerical-response Questions
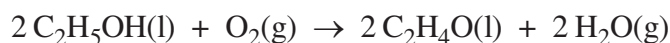
Use the following information to answer question 1.

Statements

I The reactants are glucose and oxygen.

II The reaction absorbs energy from the surroundings.

III The reaction stores energy in chemical bonds.

IV The products are carbon dioxide and liquid water.

1. The statements above that apply to photosynthesis are numbered

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

Use the following information to answer question 2.

The oxidation of ethanol, $C_2H_5OH(l)$, to ethanal, $C_2H_4O(l)$, can be represented by the following overall equation.

$$2\,C_2H_5OH(l) \;+\; O_2(g) \;\rightarrow\; 2\,C_2H_4O(l) \;+\; 2\,H_2O(g)$$

Equations

I $\quad C_2H_5OH(l) \;+\; 3\,O_2(g) \;\rightarrow\; 2\,CO_2(g) \;+\; 3\,H_2O(g) \qquad \Delta H = -1\,234.8 \text{ kJ}$

II $\quad C_2H_4O(l) \;+\; \dfrac{5}{2}\,O_2(g) \;\rightarrow\; 2\,CO_2(g) \;+\; 2\,H_2O(g) \qquad \Delta H = -1\,078.4 \text{ kJ}$

2. The enthalpy change for the oxidation of ethanol to ethanal in the overall equation is

   A. -156.4 kJ
   B. -312.8 kJ
   C. $-1\,343.2$ kJ
   D. $-4\,626.4$ kJ

A student designed a calorimetry experiment to find the molar enthalpy of combustion of methanol, $CH_3OH(l)$. The student burned 0.0345 mol of methanol to heat 0.100 kg of water in the calorimeter and assumed that all the energy was transferred to the water. The initial and final thermometer readings, in degrees Celsius, are shown below.

Initial Reading   **Final Reading**
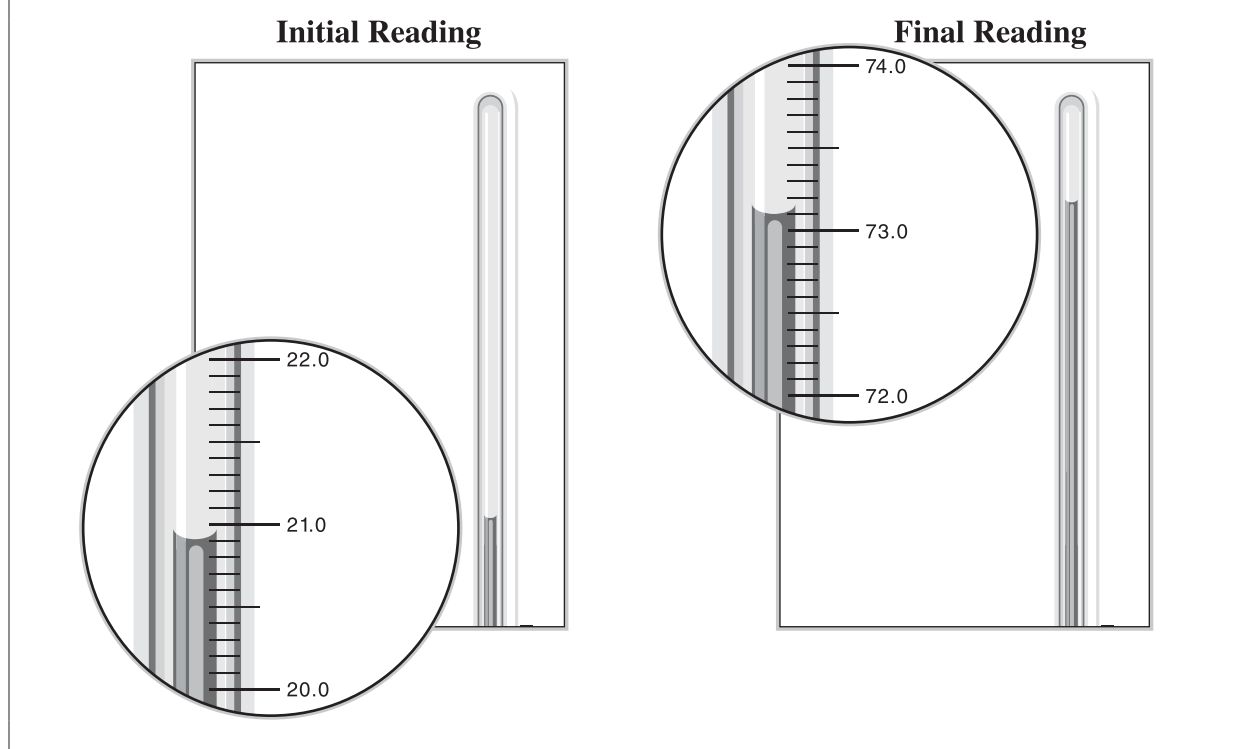
Numerical Response

1. The student's experimental value for the molar enthalpy of combustion of methanol, expressed in scientific notation, is $a.bc \times 10^d$ kJ/mol. The values of a, b, c, and d are _____, _____, _____, and _____.
         a b c d

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Use the following information to answer question 3.

A student tested two metal calorimeters of equal mass by transferring the same quantity of energy to each calorimeter. The student made the following data table for the experiment.

Calorimeter Data

Calorimeter	Mass of Calorimeter (g)	Initial Temperature (°C)	Final Temperature (°C)
Aluminium	55.0		
Tin	55.0		

3. *The calorimeter that would undergo the smaller change in temperature is the calorimeter made of ____i____ because its specific heat capacity is ____ii____ .*

The statement above is completed by the information in row

| Row	*i*	*ii*
A.	aluminium	larger
B.	aluminium	smaller
C.	tin	larger
D.	tin	smaller

Fermentation of fruits and grains converts glucose to ethanol and carbon dioxide, as represented by the following equation.

$$C_6H_{12}O_6(aq) \rightarrow 2\,C_2H_5OH(aq) + 2\,CO_2(g) + 58.4\text{ kJ}$$

4. The molar enthalpy of reaction for carbon dioxide in the fermentation reaction is

    A. –393.5 kJ/mol

    B. –116.8 kJ/mol

    C. –58.4 kJ/mol

    D. –29.2 kJ/mol

5. Which of the following is the original source of the energy stored in glucose?

    A. The Sun

    B. The cell

    C. Photosynthesis

    D. Chemical energy

Hexane, $C_6H_{14}(l)$, undergoes combustion, as represented by the following equation.

$$2\,C_6H_{14}(l) \ + \ 19\,O_2(g) \ \rightarrow \ 12\,CO_2(g) \ + \ 14\,H_2O(g) \qquad \Delta H = -7\,709.8 \text{ kJ}$$
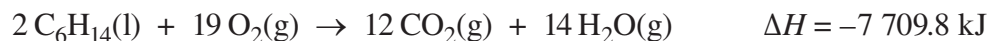
6. The standard molar enthalpy of formation, $\Delta_f H°$, for hexane is

    A.   –1 013.4 kJ/mol

    B.   –506.7 kJ/mol

    C.   –397.4 kJ/mol

    D.   –198.7 kJ/mol

Ethyne, $C_2H_2(g)$, undergoes complete combustion in a calorimeter, as represented by the following **unbalanced** equation.

$$\_\_C_2H_2(g) \ + \ \_\_O_2(g) \ \rightarrow \ \_\_CO_2(g) \ + \ \_\_H_2O(l)$$
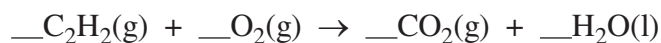
The standard molar enthalpy of combustion, $\Delta_c H°$, for ethyne is $-1\,301.1$ kJ/mol.

Numerical Response

2. When $\Delta H = -2\,602.2$ kJ, the coefficients for the above equation are

$C_2H_2(g)$ ————— (Record in the **first** box)

$O_2(g)$ ————— (Record in the **second** box)

$CO_2(g)$ ————— (Record in the **third** box)

$H_2O(l)$ ————— (Record in the **fourth** box)

(Record your answer in the numerical-response section on the answer sheet.)

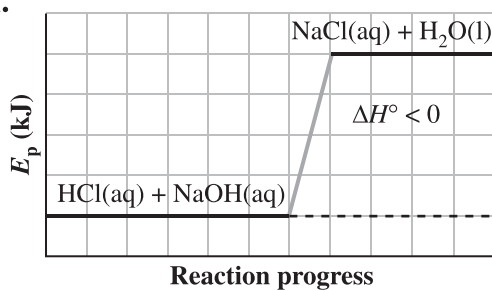**Standard Molar Enthalpies of Formation of Solutions**

Solution	$\Delta_f H°$ (kJ/mol)
NaOH(aq)	-470.3
HCl(aq)	-167.1
NaCl(aq)	-407.3

7. Which of the following potential energy diagrams illustrates the reaction of hydrochloric acid and aqueous sodium hydroxide?
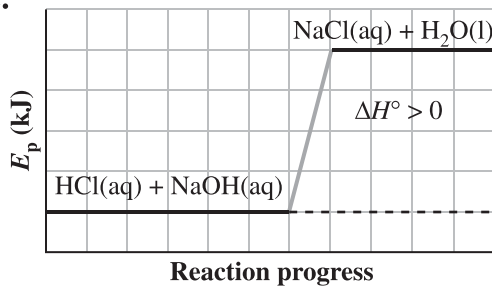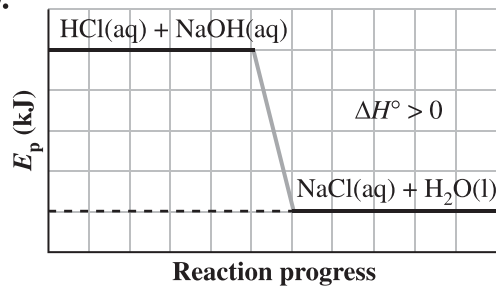
A.

NaCl(aq) + H$_2$O(l)

$\Delta H° < 0$

HCl(aq) + NaOH(aq)

E_p (kJ)

Reaction progress

B.

HCl(aq) + NaOH(aq)

$\Delta H° < 0$

NaCl(aq) + H$_2$O(l)

E_p (kJ)

Reaction progress

C.

NaCl(aq) + H$_2$O(l)

$\Delta H° > 0$

HCl(aq) + NaOH(aq)

E_p (kJ)

Reaction progress

D.

HCl(aq) + NaOH(aq)

$\Delta H° > 0$

NaCl(aq) + H$_2$O(l)

E_p (kJ)

Reaction progress

Enthalpy Diagram

E_p (kJ)

Reaction progress
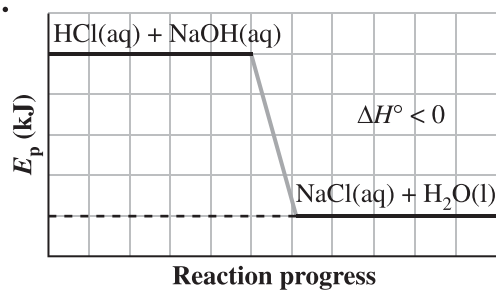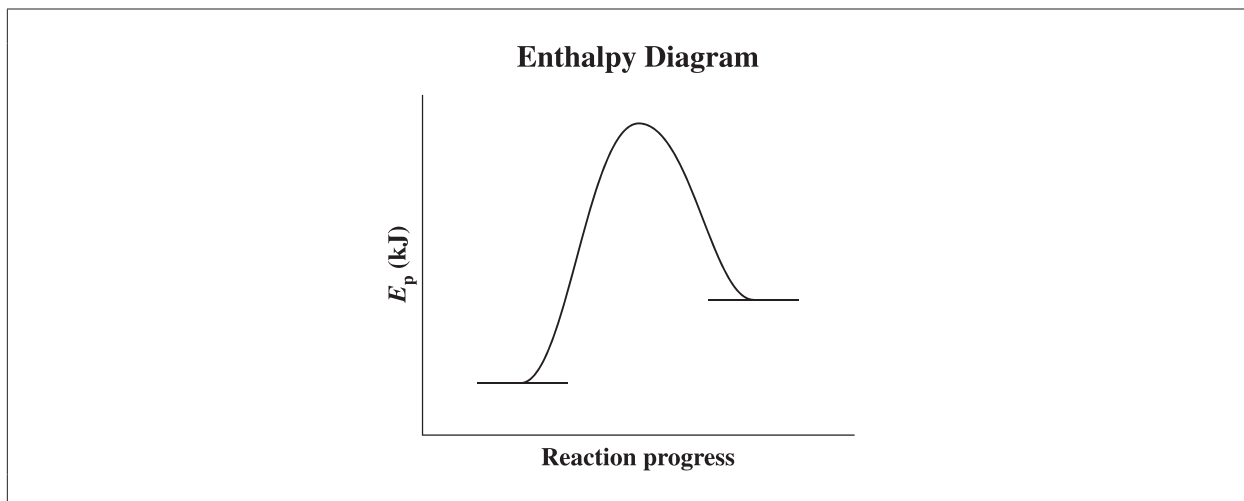
8. A correct statement about the reaction represented by the enthalpy diagram above is that the reaction is

A. exothermic and would require input energy to start it
B. exothermic and would not require input energy to start it
C. endothermic and would require the reaction enthalpy to start it
D. endothermic and would require more than the reaction enthalpy to start it

---

Reaction

$$A + B \rightleftharpoons C + D$$

Data

	Activation Energy
Forward Reaction	+70 kJ
Reverse Reaction	+80 kJ

9. For the forward reaction, which of the following rows describes the reaction type and the enthalpy of reaction for the equation represented above?

Row	Reaction Type	Enthalpy of Reaction
A.	Exothermic	–10 kJ
B.	Exothermic	+10 kJ
C.	Endothermic	–10 kJ
D.	Endothermic	+10 kJ

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Use the following information to answer numerical-response question 3.

Statements

1   Enzymes speed up digestion without being consumed.

2   A burning match is placed in a pile of wood to start a fire.

3   A catalyst is used in the Haber process to produce ammonia.

4   Electricity from the battery is used to ignite the fuel in a car.

Numerical Response

3.   Using the numbers above, match the statements above with the descriptors below. (There is more than one correct answer.)

Examples that model activation energy
in a chemical reaction are numbered _____ and _____ .
                                                                                      (Record in the   (Record in the
                                                                                       first box)   **second** box)

Examples of alternate pathways to
increase the reaction rate are numbered _____ and _____ .
                                                                                      (Record in the   (Record in the
                                                                                       third box)   **fourth** box)

(Record your answer in the numerical-response section on the answer sheet.)

Use the following information to answer questions 10 and 11.

A technician set up an experiment to test the reactivity of some uncommon metals and their ions. The technician recorded the following data.

Reactivity of Some Uncommon Metals

	Pd(s)	Zr(s)	In(s)	Ir(s)
Pd^{2+}(aq)	✗	✓	✓	✗
Zr^{4+}(aq)	✗	✗	✗	✗
In^{3+}(aq)	✗	✓	✗	✗
Ir^{3+}(aq)	✓	✓	✓	✗

✓ = evidence of a spontaneous reaction
✗ = no spontaneous reaction

10. When listed in order from **weakest** to **strongest**, the reducing agents above are

A. Ir(s), Pd(s), In(s), Zr(s)

B. Zr(s), In(s), Pd(s), Ir(s)

C. Ir^{3+}(aq), Pd^{2+}(aq), In^{3+}(aq), Zr^{4+}(aq)

D. Zr^{4+}(aq), In^{3+}(aq), Pd^{2+}(aq), Ir^{3+}(aq)

11. *If these metals and their ions were placed in a table of standard electrode potentials, the half-reaction with the **highest positive** electrical potential would contain the strongest ___i___ , and when compared to the hydrogen half-cell, this half-reaction would be located ___ii___ .*

The statement above is completed by the information in row

Row	i	ii
A.	oxidizing agent	lower
B.	oxidizing agent	higher
C.	reducing agent	lower
D.	reducing agent	higher

Certain bacteria remove nitrogen from the nitrate ions in soil and release the nitrogen as a gas, as represented by the **incomplete skeletal** half-reaction below.

$$NO_3^-(aq) \rightarrow N_2(g)$$
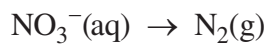
12. *During this reaction, the bacteria cause the nitrogen in $NO_3^-(aq)$ to undergo ____i____ , and, as a result, the oxidation number of nitrogen will ____ii____ .*

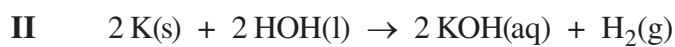The statement above is completed by the information in row

Row	i	ii
A.	oxidation	decrease
B.	oxidation	increase
C.	reduction	decrease
D.	reduction	increase

13. Which of the following rows identifies the coefficients of $NO_3^-(aq)$, $H^+(aq)$, and e^- when the nitrogen half-reaction equation above is balanced in acidic conditions?

Row	$NO_3^-(aq)$	$H^+(aq)$	e^-
A.	1	6	5
B.	1	12	11
C.	2	6	4
D.	2	12	10

Equations

|	
I	$2 K(s) + Cl_2(g) \rightarrow 2 KCl(s)$
II	$2 K(s) + 2 HOH(l) \rightarrow 2 KOH(aq) + H_2(g)$
III	$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$
IV	$2 KOH(aq) + Cl_2(g) \rightarrow KCl(aq) + KClO(aq) + H_2O(l)$

14. *An equation numbered above that would **not** represent a redox reaction is ____i____ . The equation classified as a disproportionation reaction is ____ii____ .*

The statements above are completed by the information in row

Row	*i*	*ii*
A.	either Equation II or Equation III	either Equation I or Equation IV
B.	either Equation II or Equation III	Equation IV only
C.	Equation III only	either Equation I or Equation IV
D.	Equation III only	Equation IV only

A 10.0 mL sample of acidified sodium oxalate is titrated with a 0.0200 mol/L solution of potassium permanganate, as represented by the following net equation.

$$2\,MnO_4^{\,-}(aq) + 5\,OOCCOO^{2-}(aq) + 16\,H^+(aq) \rightarrow 2\,Mn^{2+}(aq) + 10\,CO_2(g) + 8\,H_2O(l)$$
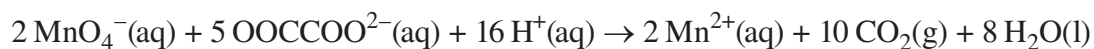
The initial and final burette readings for the titration are shown below.

Initial burette reading   Final burette reading
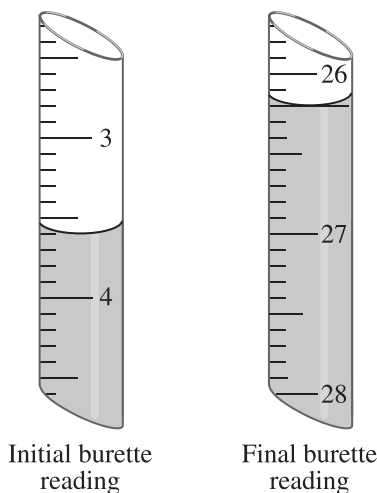
15. *In the titration experiment, the burette is filled with* ____*i*____ *, and the endpoint is reached when a single drop changes the colour of the sample from* ____*ii*____ *.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	sodium oxalate	colourless to pink
B.	sodium oxalate	pink to colourless
C.	potassium permanganate	colourless to pink
D.	potassium permanganate	pink to colourless

Numerical Response

4. The concentration of sodium oxalate in the original sample, expressed in scientific notation, is $a.bc \times 10^{-d}$ mol/L. The values of *a*, *b*, *c*, and *d* are _____, _____, _____, and _____.
                                                         a   *b*   *c*   *d*

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

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Ferroxyl indicator can be used to test for corrosion on iron surfaces. Ferroxyl indicator contains potassium ferricyanide, which turns blue to indicate the presence of Fe^{2+}(aq), and phenolphthalein, which turns pink in the presence of OH^-(aq).

A student set up an experiment in which iron nails were placed in petri dishes with a water-based gel and allowed to sit overnight. Ferroxyl indicator was added to each petri dish and the following table was compiled.

Petri Dish	Contents	Colour After Addition of Ferroxyl Indicator
1	Iron nail + H_2O(l) + O_2(g)	
2	Iron nail wrapped with zinc wire + H_2O(l) + O_2(g)	
3	Iron nail wrapped with copper wire + H_2O(l) + O_2(g)	
4	Iron nail wrapped with chromium wire + H_2O(l) + O_2(g)	

16. Which of the following equations represents the reduction half-reaction that occurs in petri dish 4?

A. Cr^{2+}(aq) $+\ 2\,e^- \rightarrow Cr$(s)

B. Fe^{2+}(aq) $+\ 2\,e^- \rightarrow Fe$(s)

C. Cr^{3+}(aq) $+\ e^- \rightarrow Cr^{2+}$(aq)

D. O_2(g) $+\ 2\,H_2O$(l) $+\ 4\,e^- \rightarrow 4\,OH^-$(aq)

Numerical Response

5. Match the petri dishes above with the colour after the addition of ferroxyl indicator. (There is more than one correct answer.)

Pink only are numbered _____ and _____.
(Record in the **first** box)   (Record in the **second** box)

Blue and pink are numbered _____ and _____.
(Record in the **third** box)   (Record in the **fourth** box)

(Record your answer in the numerical-response section on the answer sheet.)

Aluminium bicycle parts come in a variety of colours. The colour comes from dye added to the electrolyte during electrolysis. A layer of coloured aluminium oxide, $Al_2O_3(s)$, is deposited to protect the metal from corrosion, as represented by the following half-reactions.

Cathode: $2 H^+(aq) + 2 e^- \rightarrow H_2(g)$

Anode: $2 Al(s) + 3 H_2O(l) \rightarrow Al_2O_3(s) + 6 H^+(aq) + 6 e^-$
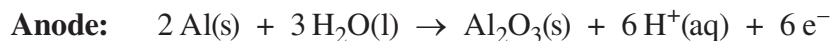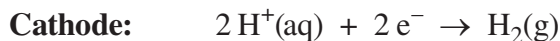
Numerical Response

6. When the half-reactions shown above are used to produce an overall net reaction equation with lowest whole-number coefficients, the

coefficient for $H_2O(l)$ is _____ (Record in the **first** box)

coefficient for $H_2(g)$ is _____ (Record in the **second** box)

total number of moles of electrons transferred is _____ (Record in the **third** box)

(Record your answer in the numerical-response section on the answer sheet.)

Electrochemical Cell

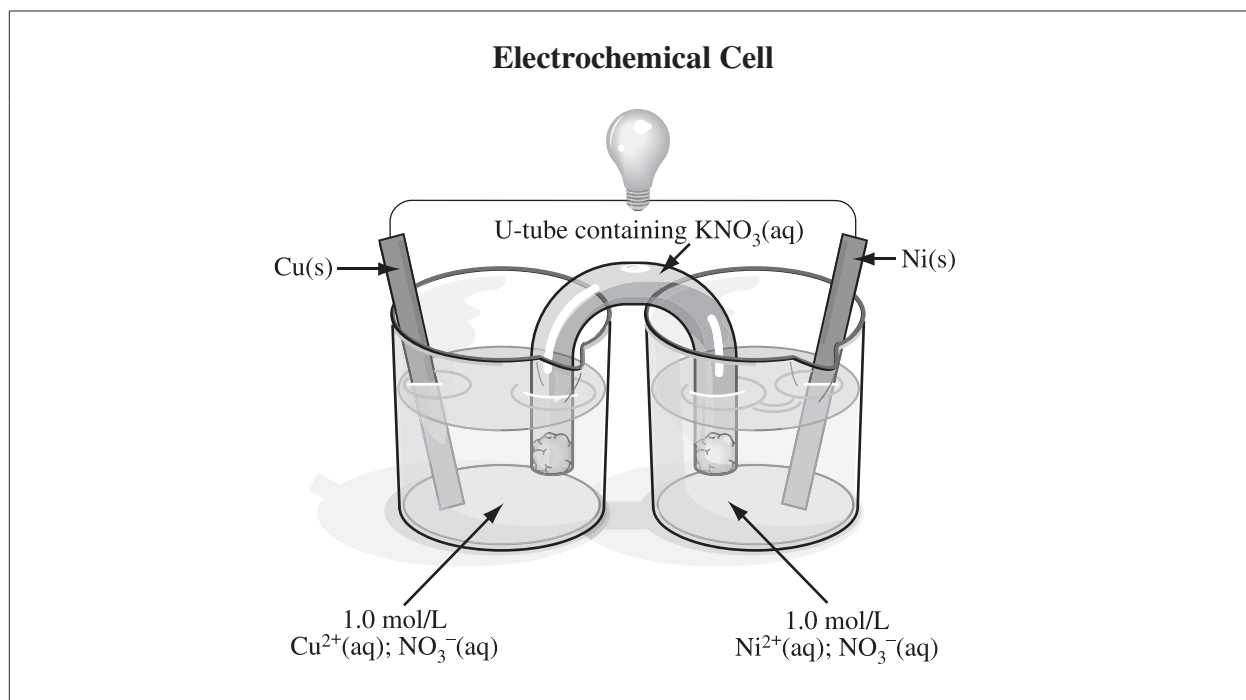$$Al(s) \,|\, Al^{3+}(aq) \,||\, Sn^{2+}(aq) \,|\, Sn(s)$$

Numerical Response

7. The standard cell potential for the cell represented above is +/–_____ V.

(Record your **three-digit answer** in the numerical–response section on the answer sheet.)

Electrochemical Cell

U-tube containing $KNO_3(aq)$

Cu(s)

Ni(s)

1.0 mol/L
$Cu^{2+}(aq)$; $NO_3^-(aq)$

1.0 mol/L
$Ni^{2+}(aq)$; $NO_3^-(aq)$

17. *In the cell above, the reducing agent* ___*i*___ *electrons, and the oxidation number of the oxidizing agent* ___*ii*___ *.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	gains	decreases
B.	gains	increases
C.	loses	decreases
D.	loses	increases

18. *During the operation of this cell, the nickel electrode acts as the* ___*i*___ *, and the colour of the nickel(II) electrolyte solution becomes* ___*ii*___ *.*

The statement above is completed by the information in row

| Row	*i*	*ii*
A.	anode	darker
B.	anode	lighter
C.	cathode	darker
D.	cathode	lighter

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19. *During the operation of this cell, the species being reduced is _____i_____ , and the mass of the copper electrode _____ii_____ .*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	$Ni^{2+}(aq)$	increases
B.	$Ni^{2+}(aq)$	decreases
C.	$Cu^{2+}(aq)$	increases
D.	$Cu^{2+}(aq)$	decreases

Use the following information to answer numerical-response question 8.

Canadian pennies were originally 95.5% copper but later became only 4.5% copper in the form of copper plating on steel.

$$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$$
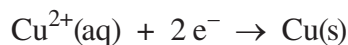
Numerical Response

8. The time, in seconds, required to plate 0.106 g of copper onto steel using a current of 15.0 A is _____ s.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer questions 20 to 23.

The citric acid cycle produces energy for living cells. Succinic acid, $C_4H_6O_4$(aq), and coenzyme Q_{10}, CoQ(aq), are important components of the citric acid cycle. Two half-reactions involved in energy production are represented by the following equations.

Half-reaction I

$$C_4H_4O_4(aq) + 2H^+(aq) + 2e^- \rightleftharpoons C_4H_6O_4(aq) \qquad E° = +0.031 \text{ V}$$

Fumaric acid   **Succinic acid**

Half-reaction II

$$CoQ(aq) + 2H^+(aq) + 2e^- \rightleftharpoons CoQH_2(aq) \qquad E° = +0.060 \text{ V}$$
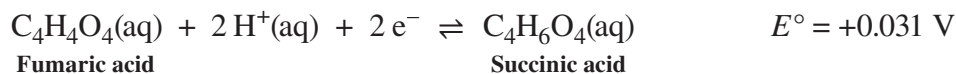
These two half-reactions produce a spontaneous reaction in the cell.

20. The oxidizing agent in the overall reaction is

    A. CoQ(aq)

    B. $CoQH_2$(aq)

    C. $C_4H_6O_4$(aq)

    D. $C_4H_4O_4$(aq)

21. The voltage generated by the overall reaction is predicted to be

    A. +0.091 V

    B. +0.029 V

    C. −0.029 V

    D. −0.091 V

22. Which of the following species could reduce CoQ(aq) to $CoQH_2$(aq)?

    A. Ag(s)

    B. Fe^{2+}(aq)

    C. Pb(s)

    D. Cu(s)

Use the following additional information to answer question 23.

Aqueous bromine was added in the absence of light to a sample of succinic acid and to a sample of fumaric acid. The line diagrams for fumaric and succinic acids are represented below.

Fumaric acid   **Succinic acid**
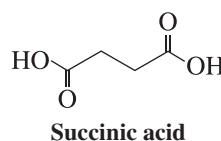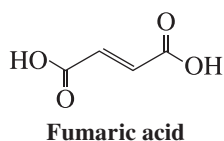
23. *The acid that would cause the bromine solution to rapidly become colourless is the ____i____ acid because this acid is classified as ____ii____ .*

The statement above is completed by the information in row

Row	i	ii
A.	succinic	saturated
B.	succinic	unsaturated
C.	fumaric	saturated
D.	fumaric	unsaturated

24. Which of the following groups of compounds contains **only** organic compounds?

A. $CH_2O(g)$, $HOOCCOOH(s)$, $C_2HBr(g)$

B. $CH_3COOCH_3(l)$, $CaC_2(s)$, $C_3H_5I(l)$

C. $CH_2Cl_2(g)$, $HCN(g)$, $CH_3OH(l)$

D. $C_2H_2(g)$, $CO(g)$, $CH_3OH(l)$

Butane, $C_4H_{10}(g)$, is used as a fuel in lighters and as a propellant in aerosol sprays. Butane is a gas at standard ambient temperature and pressure (SATP), but liquefies easily under moderate pressure.

25. Which of the following rows identifies the total number of carbon–carbon covalent bonds in a single butane molecule and the classification of butane?

Row	Total Number of Carbon–Carbon Covalent Bonds	Classification
A.	3	Unsaturated
B.	3	Aliphatic
C.	4	Unsaturated
D.	4	Aliphatic

Some Physical and Chemical Properties

1 Polar

2 Non-polar

3 Straight-chain hydrocarbon

4 Branched-chain hydrocarbon

5 Lower boiling point than ethane

6 Higher boiling point than propane

7 Undergoes substitution and addition reactions

8 Undergoes combustion and substitution reactions

Numerical Response

9. The properties above that apply to butane are numbered _____, _____, _____, and _____.

(Record all **four digits** of your answer **in any order** in the numerical-response section on the answer sheet.)

26. *In a fractional distillation tower, hydrocarbons are separated based on the physical property ___i___ . Compared to the number of carbon atoms in the molecules collected at the bottom of the tower, the number of carbon atoms in the molecules collected at the top of the tower is ___ii___ .*

The statement above is completed by the information in row

Row	i	ii
A.	melting point	greater
B.	melting point	less
C.	boiling point	greater
D.	boiling point	less

Use the following information to answer question 27.

Organic Compounds

I   1,2,4-trimethylcyclohexane

II   2,2,4,4-tetramethylpentane

III   3-ethyl-2,2-dimethylpentane

27. The organic compounds above that are isomers of nonane, C_9H_{20}(l), are

A. I only

B. I and II only

C. II and III only

D. I, II, and III

Use the following information to answer numerical-response question 10.

Boiling Points for Organic Compounds with Different Bonds and Functional Groups

Compound	Boiling Point (°C)	Compound	Boiling Point (°C)
ethane	−88.6	propane	−42.1
ethene	−103.8	propene	−47.7
ethyne	−84.7	propyne	−23.2
ethanol	+78.3	propan-1-ol	+97.2
chloroethane	+12.3	1-chloropropane	+46.5

Statements Comparing Alkanes to Their Derivatives

1 Double bonds increase the boiling point.

2 Triple bonds increase the boiling point.

3 Double bonds decrease the boiling point.

4 Triple bonds decrease the boiling point.

5 Hydroxyl functional groups increase the boiling point.

6 Chloro functional groups increase the boiling point.

7 Hydroxyl functional groups decrease the boiling point.

8 Chloro functional groups decrease the boiling point.

Numerical Response

10. The correct statements about changes in boiling point when the alkanes above are compared to their derivatives are numbered _____, _____, _____, and _____.

(Record all **four digits** of your answer **in any order** in the numerical-response section on the answer sheet.)

23

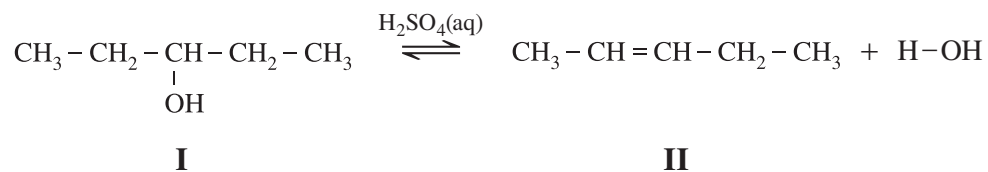The structural diagram of vitamin E is represented below.
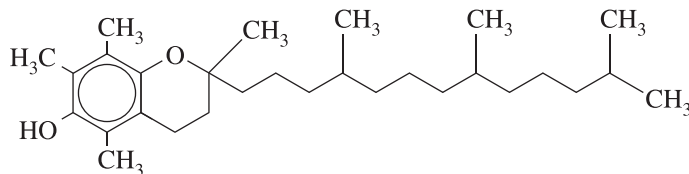
28. *Vitamin E can be classified as* ____*i*____ *and contains the functional group* ____*ii*____ *.*

The statement above is completed by the information in row

Row	i	ii
A.	aromatic	ester
B.	aromatic	hydroxyl
C.	aliphatic	ester
D.	aliphatic	hydroxyl

Use the following information to answer question 29.

Pentan-3-ol is heated in the presence of a sulfuric acid catalyst, as represented by the following equilibrium equation.

$$CH_3 - CH_2 - \underset{\underset{OH}{|}}{CH} - CH_2 - CH_3 \quad \overset{H_2SO_4(aq)}{\rightleftharpoons} \quad CH_3 - CH = CH - CH_2 - CH_3 \ + \ H-OH$$

I   **II**

29. *In the reaction represented by the equation above, the type of reaction pentan-3-ol is undergoing is an* ___*i*___ *, and the H₂SO₄(aq) acts to* ___*ii*___ *.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	elimination reaction	speed up the rate of reaction
B.	elimination reaction	shift the equilibrium to the right
C.	esterification reaction	speed up the rate of reaction
D.	esterification reaction	shift the equilibrium to the right

25

An Ester
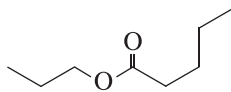
30. The ester represented by the line diagram above was formed by the reactants

A. $CH_3-CH_2-CH_2-OH$ + $\overset{\overset{\text{O}}{\|}}{CH}-CH_2-CH_2-CH_2-CH_3$

B. $CH_3-CH_2-CH_2-OH$ + $HO-\overset{\overset{\text{O}}{\|}}{C}-CH_2-CH_2-CH_2-CH_3$

C. $CH_3-CH_2-CH_2-\overset{\overset{\text{O}}{\|}}{C}-OH$ + $CH_3-CH_2-CH_2-CH_2-CH_3$

D. $CH_3-CH_2-CH_2-\overset{\overset{\text{O}}{\|}}{C}-OH$ + $HO-CH_2-CH_2-CH_2-CH_2-CH_3$

Equations for the Formation of Greenhouse Gases

1    $CH_4(g)$ + $2\,Cl_2(g)$ + $2\,F_2(g)$ → $CCl_2F_2(g)$ + $2\,HCl(g)$ + $2\,HF(g)$

2    $NH_4NO_3(aq)$ → $N_2O(g)$ + $2\,H_2O(l)$

3    $C_3H_8(g)$ + $5\,O_2(g)$ → $3\,CO_2(g)$ + $4\,H_2O(g)$

4    $C_2H_2(g)$ + $Cl_2(g)$ + $F_2(g)$ → $C_2Cl_2F_2H_2(g)$

Numerical Response

11. Match the equations for the formation of greenhouse gases above with the reaction types below.

The hydrocarbon combustion reaction is numbered _____. (Record in the **first** box)

The substitution reaction is numbered _____. (Record in the **second** box)

The inorganic reaction is numbered _____. (Record in the **third** box)

The addition reaction is numbered _____. (Record in the **fourth** box)

(Record your answer in the numerical-response section on the answer sheet.)

Polyethylene terephthalate, commonly abbreviated as PET, is used to make polyester textiles and beverage containers. The reaction to produce PET can be represented by the following polymerization reaction.

| terephthalic acid | ethylene glycol | PET |
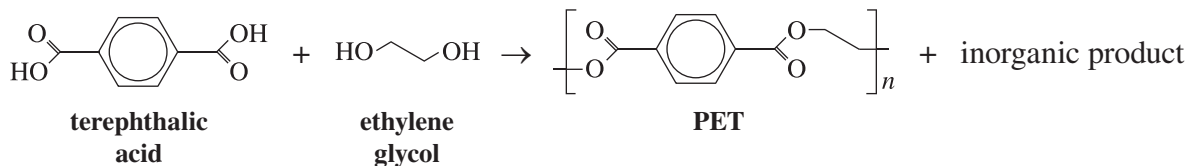
31. *The polymerization reaction above can be classified as* ___*i*___ *, and the inorganic product is* ___*ii*___ .

The statement above is completed by the information in row

Row	*i*	*ii*
A.	a condensation reaction	$H_2(g)$
B.	a condensation reaction	$H_2O(l)$
C.	an addition reaction	$H_2(g)$
D.	an addition reaction	$H_2O(l)$

$$K_c = \frac{\left[Br^-(aq)\right]\left[Cr_2O_7^{2-}(aq)\right]\left[H^+(aq)\right]^8}{\left[BrO_3^-(aq)\right]\left[Cr^{3+}(aq)\right]^2}$$

32. Which of the following represents the balanced equation for the equilibrium law expression given above?

A. $BrO_3^-(aq) + 2\,Cr^{3+}(aq) \rightleftharpoons Br^-(aq) + Cr_2O_7^{2-}(aq) + 8\,H^+(aq)$

B. $Br^-(aq) + Cr_2O_7^{2-}(aq) + 8\,H^+(aq) \rightleftharpoons BrO_3^-(aq) + 2\,Cr^{3+}(aq)$

C. $BrO_3^-(aq) + 2\,Cr^{3+}(aq) + 4\,H_2O(l) \rightleftharpoons Br^-(aq) + Cr_2O_7^{2-}(aq) + 8\,H^+(aq)$

D. $Br^-(aq) + Cr_2O_7^{2-}(aq) + 8\,H^+(aq) \rightleftharpoons BrO_3^-(aq) + 2\,Cr^{3+}(aq) + 4\,H_2O(l)$

Polystyrene, a plastic used for insulation, is manufactured from styrene, $C_6H_5CHCH_2(g)$. Styrene is produced from ethylbenzene, $C_6H_5CH_2CH_3(g)$, as represented by the following equation.

$$C_6H_5CH_2CH_3(g) + energy \rightleftharpoons C_6H_5CHCH_2(g) + H_2(g)$$
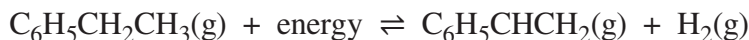
Equilibrium Concentrations

$$[C_6H_5CH_2CH_3(g)] = 0.330 \text{ mol/L}$$

$$[C_6H_5CHCH_2(g)] = 0.540 \text{ mol/L}$$

$$[H_2(g)] = 1.20 \text{ mol/L}$$

33. *If the equilibrium system represented by the equation above was heated, the value of the equilibrium constant would ____i____ and the concentration of $C_6H_5CH_2CH_3(g)$ would ____ii____ .*

The statement above is completed by the information in row

| Row	i	ii
A.	not change	decrease
B.	not change	increase
C.	increase	decrease
D.	increase	increase

Numerical Response

12. The value of the equilibrium constant, K_c, for the system at equilibrium represented by the equation above is _____ .

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Syngas is a mixture containing carbon monoxide gas, CO(g), and hydrogen gas, H_2(g), that is used in industry to manufacture other products. One method of producing syngas is through a steam reforming reaction, as represented by the following equilibrium equation.

$$CH_4(g) + H_2O(g) + energy \xrightleftharpoons{\text{catalyst}} CO(g) + 3\,H_2(g)$$
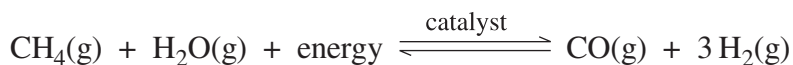
34. An increase in pressure on the syngas equilibrium system because of a slow decrease in system volume would

    A. shift the equilibrium to the left and increase the number of moles of methane gas

    B. shift the equilibrium to the right and decrease the number of moles of methane gas

    C. not shift the equilibrium, and the moles of methane gas would remain constant

    D. increase both the forward and the reverse reaction rates, and the equilibrium constant would not change

---

A technician added CS_2(g), H_2(g), CH_4(g), and H_2S(g) to an empty 1.00 L container at 960 °C and allowed the contents of the container to reach equilibrium, as represented by the following equation.

$$CS_2(g) + 4\,H_2(g) \rightleftharpoons CH_4(g) + 2\,H_2S(g)$$
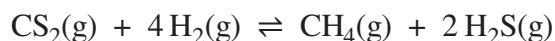
The technician records the following data.

	CS_2(g)	H_2(g)	CH_4(g)	H_2S(g)
Initial concentration (mol/L)	2.00	4.00	2.00	4.00
Equilibrium concentration (mol/L)	1.25	?		?

35. *The equilibrium concentration of H_2(g) is* ____*i*____ *mol/L, and the equilibrium concentration of H_2S(g) is* ____*ii*____ *mol/L.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	3.25	2.50
B.	3.25	5.50
C.	1.00	2.50
D.	1.00	5.50

Equilibrium System

$$N_2O_4(g) \rightleftharpoons 2\,NO_2(g)$$
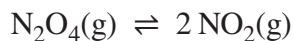
A mixture containing $N_2O_4(g)$ and 0.430 mol of $NO_2(g)$ was added to a 1.00 L flask. The flask was sealed and the contents were allowed to reach equilibrium, as represented by the sketch below.
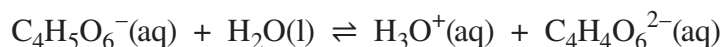
Changes to the Equilibrium System

$[N_2O_4(g)] = 0.491$ mol/L

$[NO_2(g)] = 0.0475$ mol/L

Concentration (mol/L)

Time (s)
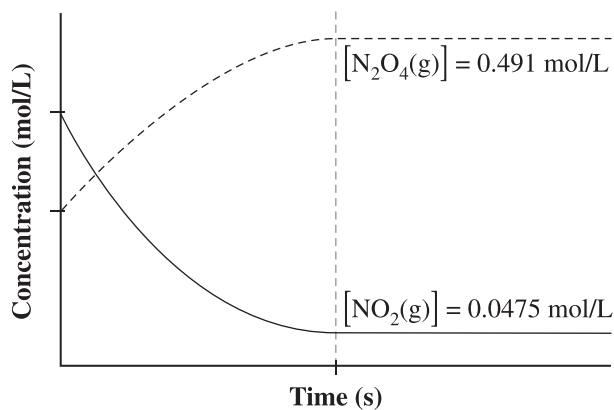
36. *The change in the concentration of $N_2O_4(g)$ was ____i____ mol/L, and the initial concentration of $N_2O_4(g)$ was ____ii____ mol/L.*

The statement above is completed by the information in row

Row	i	ii
A.	0.191	0.300
B.	0.191	0.682
C.	0.383	0.108
D.	0.383	0.874

Bitartrate System

$$C_4H_5O_6^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + C_4H_4O_6^{2-}(aq)$$

Possible Terms in the Equilibrium Law Expression for the System

1   K_a

2   K_w

3    $C_4H_4O_6^{2-}(aq)$

4    $H_2O(l)$

5    $H_3O^+(aq)$

6    $C_4H_5O_6^-(aq)$

7    $OH^-(aq)$

Equilibrium Law Expression for the System

$$W = \frac{[X][Y]}{[Z]}$$

Numerical Response

13. Match the numbers above with their correct position in the equilibrium law expression for the bitartrate system. There is more than one correct answer.

Term number:	_____	_____	_____	_____
Equilibrium law position:	*W*	*[X]*	*[Y]*	*[Z]*

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

37. Which of the following stresses would increase the amount of products produced in the forward reaction of the bitartrate system?

A. Adding HCl(aq)

B. Adding a catalyst

C. Increasing the pressure of the system

D. Increasing the concentration of $C_4H_5O_6^-(aq)$

A student prepared a solution of nitrous acid, $HNO_2(aq)$, as represented by the following equilibrium equation.

$$HNO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NO_2^-(aq)$$
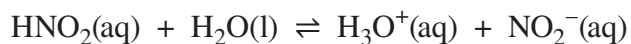
38. Which of the following rows identifies the Brønsted–Lowry bases and a conjugate acid–base pair in the equation above?

Row	Brønsted–Lowry Bases	Conjugate Acid–Base Pair
A.	$HNO_2(aq)$ and $NO_2^-(aq)$	$H_2O(l)$ and $H_3O^+(aq)$
B.	$HNO_2(aq)$ and $NO_2^-(aq)$	$HNO_2(aq)$ and $H_3O^+(aq)$
C.	$H_2O(l)$ and $NO_2^-(aq)$	$H_2O(l)$ and $H_3O^+(aq)$
D.	$H_2O(l)$ and $NO_2^-(aq)$	$HNO_2(aq)$ and $H_3O^+(aq)$

Numerical Response

14. The value of K_b for the conjugate base of nitrous acid, expressed in scientific notation, is $a.b \times 10^{-cd}$. The values of a, b, c, and d are _____, _____, _____, and _____.
$\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad a \quad\quad b \quad\quad c \quad\quad\quad d$

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Species	Molecular Formula	Structural Diagram	Trend in Equilibrium Constants
1	$C_4H_4O_5$		
2	$C_4H_3O_5^-$		
3	$C_4H_2O_5^{2-}$		

K_a increases ↑ K_b increases ↓

Numerical Response

15. Match the species numbered above with the descriptions given below. You may use a number more than once.

The species that is amphiprotic is numbered _____. (Record in the **first** box)

The species that is
the conjugate base of $C_4H_3O_5^-$(aq) is numbered _____. (Record in the **second** box)

The species that is
the conjugate acid of $C_4H_3O_5^-$(aq) is numbered _____. (Record in the **third** box)

The species with
the weakest conjugate base is numbered _____. (Record in the **fourth** box)

(Record your answer in the numerical-response section on the answer sheet.)

39. Which of the following rows correctly identifies the species that, in a Brønsted–Lowry neutralization, would **most readily donate** a proton and the species that would **most readily accept** a proton?

Row	Most Readily Donates a Proton	Most Readily Accepts a Proton
A.	Species 1	Species 2
B.	Species 1	Species 3
C.	Species 3	Species 1
D.	Species 3	Species 2

Benzoic acid, $C_6H_5COOH(aq)$, is used as a food preservative. A 0.070 mol/L solution of benzoic acid undergoes partial ionization, as represented by the following equilibrium equation.

$$C_6H_5COOH(aq) + H_2O(l) \rightleftharpoons C_6H_5COO^-(aq) + H_3O^+(aq)$$
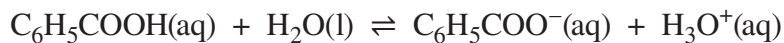
40. In this benzoic acid solution, the

    A.   benzoic acid concentration is equal to the benzoate ion concentration

    B.   benzoic acid concentration is greater than the benzoate ion concentration

    C.   hydronium ion concentration is equal to the benzoic acid concentration

    D.   hydronium ion concentration is greater than the benzoic acid concentration

Numerical Response

16. The pH of a 0.070 mol/L benzoic acid solution is _____ .

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

41. *Compared to carbonic acid, $H_2CO_3(aq)$, benzoic acid is a* ___*i*___ *and compared to the hydrogen carbonate ion, the benzoate ion is a* ___*ii*___ *.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	stronger acid	weaker base
B.	stronger acid	stronger base
C.	weaker acid	weaker base
D.	weaker acid	stronger base

42. *If the pH of a solution changes from 2 to 5, then the hydronium ion concentration will change by a factor of _____i_____ and the pOH of the solution will change from _____ii_____ .*

The statement above is completed by the information in row

Row	i	ii
A.	2.5	9 to 12
B.	2.5	12 to 9
C.	1 000	9 to 12
D.	1 000	12 to 9

43. *A buffer solution could be made by mixing equal amounts of citric acid and a solution containing _____i_____ . When a small amount of strong acid or base is added, this buffer would resist _____ii_____ .*

The statements above are completed by the information in row

Row	i	ii
A.	$C_3H_5O(COO)_3{}^{3-}(aq)$	a pH change
B.	$C_3H_5O(COO)_3{}^{3-}(aq)$	an equilibrium shift
C.	$C_3H_5O(COOH)_2COO^-(aq)$	a pH change
D.	$C_3H_5O(COOH)_2COO^-(aq)$	an equilibrium shift

pH as a Function of Volume of KOH(aq)
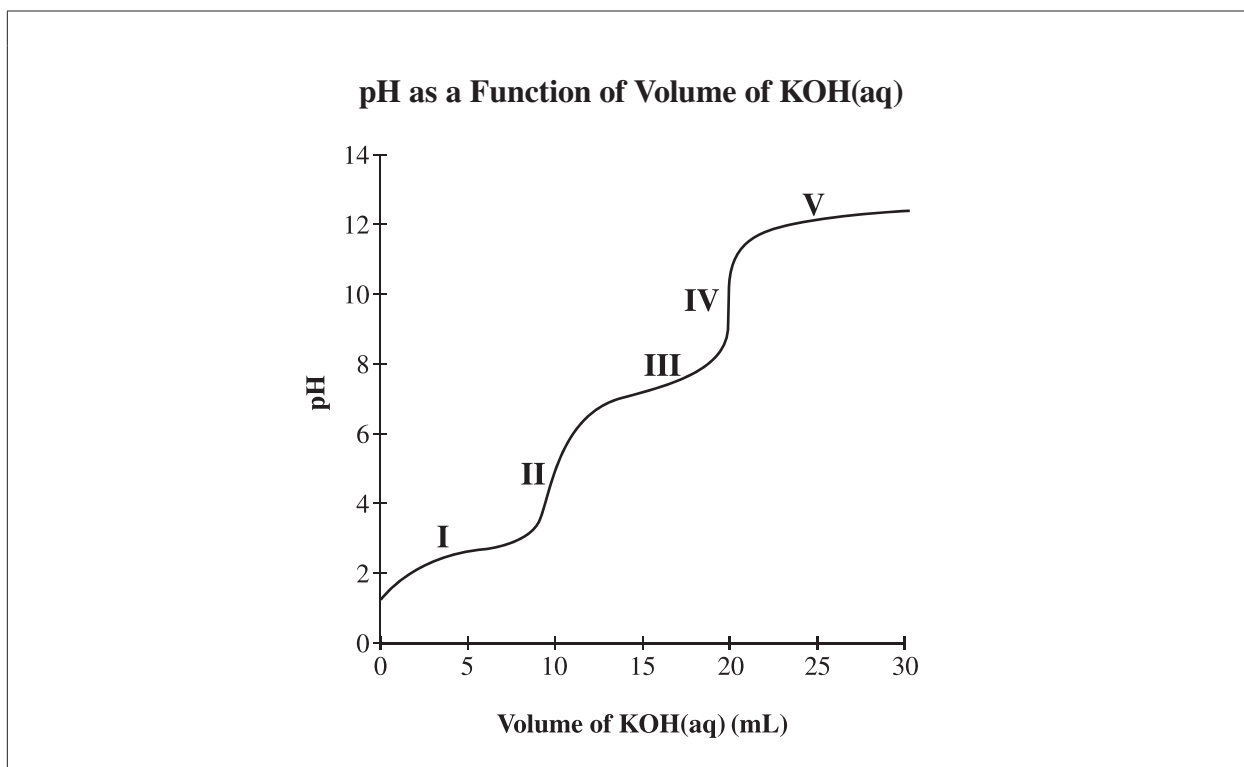
44. *On the titration curve above, the hydronium ion concentration, $[H_3O^+(aq)]$, is **less** than the hydroxide ion concentration, $[OH^-(aq)]$, at the region labelled* ___**i**___ . *In the determination of endpoints, thymol blue would be an appropriate indicator to identify* ___**ii**___ .

The statements above are completed by the information in row

Row	*i*	*ii*
A.	II	one endpoint
B.	II	both endpoints
C.	IV	one endpoint
D.	IV	both endpoints