Multiple Choice

1. Which of the following types of compounds has the strongest intermolecular forces?
a) alcohol
b) alkyl halide
c) ester
d) carboxylic acid

2. In an organic substitution reaction,
a) multiple bonds are broken
b) multiple bonds are created
c) there is no change to bonds between carbon atoms
d) many small molecules are linked together

3. What type of reaction could convert cyclobutanol into cyclobutene and water?
a) substitution
b) esterification
c) addition
d) elimination

4. Which of the following is an isomer of cyclohexene?
a) hexane
b) benzene
c) hex-1-yne
d) hex-1-ene

5. Name the following compound:

```
    H
    |
    C
   |||
    C
    |
   CH – CH3
    |
   CH3
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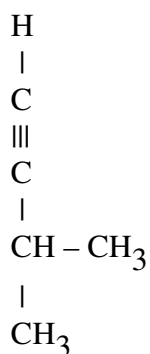
a) 2-methylbut-3-yne
b) 3-methylbut-1-yne
c) 3-methylbut-1-ene
d) 2-methylbut-3-ene

6. In an exothermic chemical reaction,
(a) The products have lower E_P than the reactants.
(b) The products have higher E_P than the reactants.
(c) The products have negative E_P.
(d) The reactants have negative E_P.
(e) Both products and reactants have negative E_P.

7. The combustion of $N_2H_{4(g)}$ with oxygen produces water vapour and
   nitrogen dioxide gas. The molar enthalpy of combustion for $N_2H_{4(g)}$ is –428.3 kJ/mol.

What is the molar enthalpy for nitrogen dioxide in this reaction?
a) –428.3 kJ/mol
b) +11.1 kJ/mol
c) –856.6 kJ/mol
d) –214.2 kJ/mol
e) +33.2 kJ/mol

8. A chemical reaction can be described as …
a) A change in a system's potential energy due to changing bonds.
b) A change in a system's kinetic energy due to changing bonds.
c) A change in a system's potential energy due to changing particle speed.
d) A change in a system's kinetic energy due to changing particle speed.

9. **Use the following diagram to answer this question:**
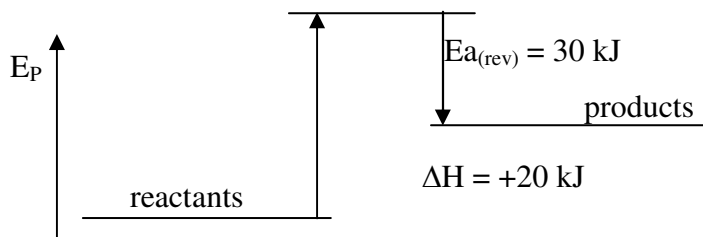
What is the activation energy for the forward reaction?
a) 50 kJ
b) 20 kJ
c) 30 kJ
d) -20 kJ

10. Which of the following would be the most thermally stable?
(a) nitrogen monoxide
(b) barium carbonate
(c) carbon dioxide
(d) hydrogen bromide

11. Which of the following reactions is exothermic?
a) simple decomposition of methane
b) formation of nitrogen monoxide gas
c) formation of propane
d) simple decomposition of ethane

12. Which statement best describes an oxidizing agent?
a) An oxidizing agent gains electrons and is reduced.
b) An oxidizing agent loses electrons and is reduced.
c) An oxidizing agent gains electrons and is oxidized.
d) An oxidizing agent loses electrons and is oxidized.

13. Which of the following will oxidize zinc metal and reduce solid iodine?
a) $Sn^{2+}_{(aq)}$
b) $Fe^{2+}_{(aq)}$
c) $Co^{2+}_{(aq)}$
d) $Cr^{2+}_{(aq)}$

14. The oxidation number of Chlorine in the chlorite ion is
a) +5
b) -3
c) -5
d) +3

15. Which of the following is **not** a redox reaction?
a) $Pb_{(s)} + 2AgNO_{3(aq)} \rightarrow Pb(NO_3)_{2(aq)} + 2Ag_{(s)}$
b) $H_2O_{(g)} \rightarrow H_{2(g)} + \frac{1}{2}O_{2(g)}$
c) $Ca(NO_3)_{2(aq)} + 2KCl_{(aq)} \rightarrow CaCl_{2(s)} + 2KNO_{3(aq)}$
d) $CH_{4(g)} + 2O_{2(g)} \rightarrow 2H_2O_{(g)} + CO_{2(g)}$

16. An acidified solution of potassium dichromate is to be stored in a metal container. Which metal would be the best choice for the container?
a) Aluminum
b) Silver
c) Gold
d) Chromium

17. Which statement best describes the functions of a salt bridge in a voltaic cell?
a) Separate SOA from SRA; allow ions to pass through.
b) Separate SOA from SRA; allow electrons to pass through.
c) Allow contact between SOA and SRA; allow electrons to pass through.
d) Allow contact between SOA and SRA; allow ions to pass through.

18. Which of the following is true for voltaic and electrolytic cells?
a) SRA is reduced at the cathode.
b) SOA is reduced at the cathode.
c) SRA is reduced at the anode.
d) SOA is reduced at the anode.

19. Which statement best describes an inert electrode ?
a) An inert electrode is non-reactive and conductive.
b) An inert electrode is non-reactive, and not conductive.
c) An inert electrode is reactive, and not conductive.
d) An inert electrode is reactive and conductive.

20. In what type of half cell would an inert electrode typically be used?
a) A half cell which contains no electrolyte.
b) A half cell which contains no solid metal.
c) A half cell which contains an inert gas.
d) A half cell which contains inert ions.

21. Which statement best describes a reference half cell?
a) A half cell in which all aqueous species have concentration = 1.0 mol/L
b) A half cell which contains no solid metal.
c) A half cell which is assigned a reduction potential of 0.00 V
d) A half cell which is inert.

22. What is the effect of a catalyst on an equilibrium?
a) shift to more molecules
b) shift to fewer molecules
c) equilibrium is achieved more quickly
d) equilibrium is achieved more slowly

23. **Dynamic Equilibrium** is defined as
(a) A balance between concentrations of reactants and products.
(b) A balance between forward and reverse reactions happening at the same rate.
(c) A balance between concentrations of H^+ and OH^- ions.
(d) A balanced chemical reaction happening at a constant rate.

24. Nitrous acid is titrated with aqueous sodium phosphate.
Which statement best describes the pH at the equivalence point?
(a) pH = 0
(b) pH = 7
(c) pH > 7
(d) pH < 7

25. Nitrogen gas reacts with hydrogen gas to produce ammonia gas.
    The equilibrium could be **shifted towards products** by
(a) decreasing $[N_{2(g)}]$
(b) decreasing $[H_{2(g)}]$
(c) increasing volume
(d) decreasing volume

26. For an exothermic forward reaction, what is the effect of increasing temperature?
a) equilibrium shifts to products
b) equilibrium shifts to reactants
c) equilibrium does not shift
d) equilibrium shifts to fewer molecules

27. What is the pH of a 0.10 mol/L solution of hydrosulfuric acid?
(a) 2.0
(b) 4.0
(c) 1.0
(d) 0.10

28. What is the **Bronsted-Lowry** definition of an **acid**?
a) An acid is a proton acceptor.
b) An acid reacts with water to produce H^+ ions.
c) An acid is a proton donor.
d) An acid reacts with water to produce H_3O^+ ions.

29. Nitrous acid is titrated with aqueous ammonia.
Which statement best describes the pH at the equivalence point?
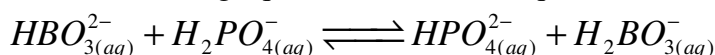a) pH = 0
b) pH = 7
c) pH > 7
d) pH < 7

30. A certain solution was tested with two indicators, giving the following evidence:

Indicator	Observed Colour
Phenol Red	Yellow
Chlorophenol Red	Yellow

   Predict the colour of Indigo Carmine in this solution.
a) blue
b) red
c) yellow
d) orange

Use the following equilibrium to answer questions 31 and 32:

$$HBO_{3(aq)}^{2-} + H_2PO_{4(aq)}^{-} \rightleftharpoons HPO_{4(aq)}^{2-} + H_2BO_{3(aq)}^{-}$$

31. Identify the species that are acting as bases according to the Bronsted-Lowry theory.

a) $HBO_{3(aq)}^{2-}$ and $H_2PO_{4(aq)}^{-}$

b) $HPO_{4(aq)}^{2-}$ and $H_2BO_{3(aq)}^{-}$

c) $H_2PO_{4(aq)}^{-}$ and $H_2BO_{3(aq)}^{-}$

d) $HBO_{3(aq)}^{2-}$ and $HPO_{4(aq)}^{2-}$

32. Identify the conjugate pairs.

a) $HBO_{3(aq)}^{2-} / H_2PO_{4(aq)}^{-}$ and $HPO_{4(aq)}^{2-} / H_2BO_{3(aq)}^{-}$

b) $HBO_{3(aq)}^{2-} / HPO_{4(aq)}^{2-}$ and $H_2PO_{4(aq)}^{-} / H_2BO_{3(aq)}^{-}$

c) $H_2PO_{4(aq)}^{-} / HPO_{4(aq)}^{2-}$ and $HBO_{3(aq)}^{2-} / H_2BO_{3(aq)}^{-}$

d) $H_2PO_{4(aq)}^{2-} / HPO_{4(aq)}^{-}$ and $HBO_{3(aq)}^{-} / H_2BO_{3(aq)}^{2-}$

33. What is a buffer?
a) A conjugate acid-base pair which is in equilibrium.
b) A conjugate acid-base pair which maintains almost constant pH.
c) A conjugate acid-base pair which changes colour at a certain pH.
d) A conjugate acid-base pair which experiences a sharp change in pH.

Written Section

1. At 448°C, the equilibrium constant for the following reaction is $K_c = 50$.
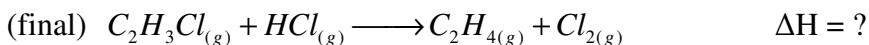
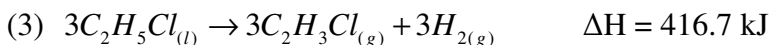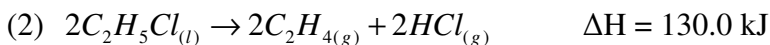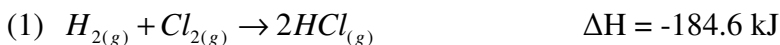 $$I_{2(g)} + H_{2(g)} \rightleftharpoons 2HI_{(g)}$$
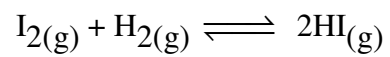
   Initially, a closed 10.0 L container has 4.0 mol of hydrogen gas and 4.0 mol of iodine gas.

   Calculate the equilibrium concentration of $HI_{(g)}$

2. Rearrange the reactions (1), (2) and (3) to find the ΔH for the final reaction:
    No marks will be given for directly calculating ΔH from the standard molar enthalpies
    of formation. You must show the modified reactions.

    [4]

(1) $H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$ ΔH = -184.6 kJ

(2) $2C_2H_5Cl_{(l)} \rightarrow 2C_2H_{4(g)} + 2HCl_{(g)}$ ΔH = 130.0 kJ

(3) $3C_2H_5Cl_{(l)} \rightarrow 3C_2H_3Cl_{(g)} + 3H_{2(g)}$ ΔH = 416.7 kJ

(final) $C_2H_3Cl_{(g)} + HCl_{(g)} \longrightarrow C_2H_{4(g)} + Cl_{2(g)}$ ΔH = ?

3. a) Use **oxidation numbers** to balance the following reaction in acidic solution.
    b) Derive **half reactions** to balance the following reaction in acidic solution.   [5]

$$ThO_{2(aq)} + U_{(s)} \rightarrow Th_{(s)} + U^{3+}_{(aq)}$$
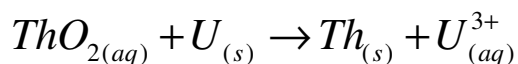
4. A piece of solid iodine is placed in an acidic solution of
    aqueous chromium (II) chloride.
    Write a net ionic equation showing the most likely redox reaction.
    Is the reaction spontaneous?

5. A hot water heater uses natural gas as a fuel. What mass of natural gas must be
    completely combusted to raise the temperature of 46.3 litres of water by 35.0˚C ?
    Assume 100% of the energy released by the combustion of natural gas is absorbed by
   the water.

6. An acidic primary standard solution of $SnCl_{2(aq)}$ has a concentration of 0.0500 mol/L. 20.0 mL samples of this primary standard are titrated with $KMnO_{4(aq)}$, as shown below.

Volume of $KMnO_{4(aq)}$ required to react with 20.0 mL of acidified $SnCl_{2(aq)}$

	Trial #1	Trial #2	Trial #3	Trial #4
Final Buret Reading (mL)	18.4	35.3	17.3	34.1
Initial Buret Reading (mL)	1.0	18.4	0.6	17.3
Volume of $KMnO_{4(aq)}$ used				

Calculate the concentration of $KMnO_{4(aq)}$.

7. Complete (a), (b), (c), (d) and (e) for the following cell:
$C(s) \mid Cr^{2+}_{(aq)}, I^-_{(aq)} \mid C(s)$
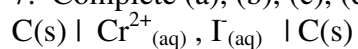
(a) Cathode half reaction   [1]

(b) Anode half reaction   [1]

(c) Net ionic equation. Is it spontaneous?   [2]

(d) Standard cell potential $= \Delta E°$ [1]

(e) Draw a diagram of this cell, showing **anode**, **cathode**, direction of flow for **electrons**, and **ions**. Use $+$ to indicate the positive electrode and $-$ to indicate the negative electrode.
         Show the connection to an external voltage source.

8. Carbon monoxide gas reacts with oxygen gas to produce carbon dioxide gas.
(a) Write a balanced chemical reaction for this process.   [1]

(b) Write the equilibrium law.   [1]

(c) How would a temperature increase shift the equilibrium? Explain your answer.
                                                      [2]

(d) How would an increase in total volume shift the equilibrium? Explain your answer.
(assume all reactants and products are initially present in a closed system)   [1]

(e) Use the following data to calculate the equilibrium constant.
(all concentrations are in mol/L)

	$[CO_{(g)}]$	$[O_{2(g)}]$	$[CO_{2(g)}]$
Initial	3.30	3.30	0
Change			
Equilibrium	2.15		

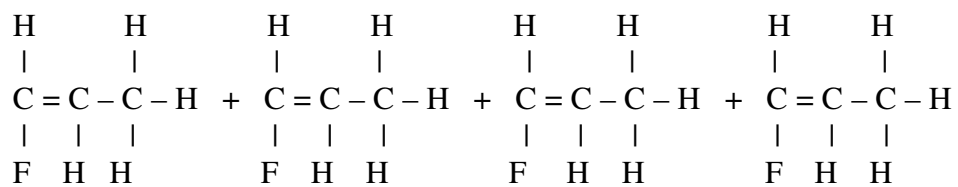   [5]

(f) Are the products or reactants favoured?

9. What concentration of ammonia would produce a solution with pH = 12.00 ?

10. Draw the product(s) of this polymerization reaction.
    Show at least 2 monomer units (with appropriate linkages) in the final polymer.
    [2]

```
 H      H           H      H           H      H           H      H
 |      |           |      |           |      |           |      |
 C = C – C – H  +   C = C – C – H  +   C = C – C – H  +   C = C – C – H
 |   |   |          |   |   |          |   |   |          |   |   |
 F   H   H          F   H   H          F   H   H          F   H   H
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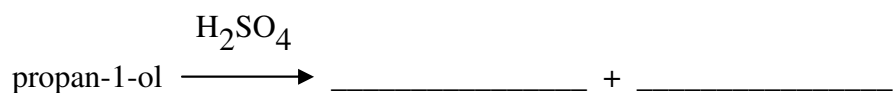
11. What reactant(s) would be needed to produce ethyl methanoate from an esterification reaction?
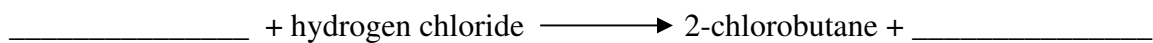   Write the name(s) and draw structural formula(s) for the reactant(s).

12. Write the **names** and draw **structural formulas** of any missing reactants and/or products in the following reactions:

a) elimination reaction: [2]

$$H_2SO_4$$
propan-1-ol ⟶ _____ + _____

b) substitution reaction: [2]
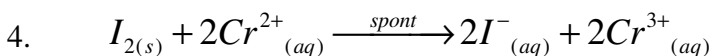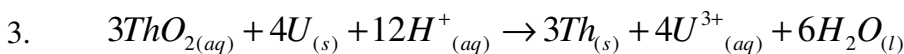
_____ + hydrogen chloride ⟶ 2-chlorobutane + _____

<u>Multiple Choice</u>

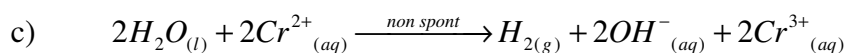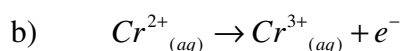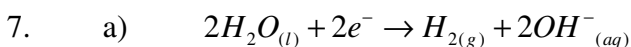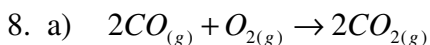|		
1. D	2. C	3. D
4. C	5. B	6. A
7. D	8. A	9. A
10. B	11. C	12. A
13. A	14. D	15. C
16. C	17. A	18. B
19. A	20. B	21. C
22. C	23. B	24. C
25. D	26. B	27. B
28. C	29. D	30. A
31. D	32. C	33. B

Written Section

1.   0.62 mol/L

2.   +110.7 kJ

3. $3ThO_{2(aq)} + 4U_{(s)} + 12H^+_{(aq)} \rightarrow 3Th_{(s)} + 4U^{3+}_{(aq)} + 6H_2O_{(l)}$

4. $I_{2(s)} + 2Cr^{2+}_{(aq)} \xrightarrow{\quad spont \quad} 2I^-_{(aq)} + 2Cr^{3+}_{(aq)}$

5.   136 g

6. $[KMnO_{4(aq)}] = [MnO4^-_{(aq)}] = 2.38 \times 10^{-2}$ mol/L

7.   a) $2H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$

        b) $Cr^{2+}_{(aq)} \rightarrow Cr^{3+}_{(aq)} + e^-$

        c) $2H_2O_{(l)} + 2Cr^{2+}_{(aq)} \xrightarrow{\quad non\ spont \quad} H_{2(g)} + 2OH^-_{(aq)} + 2Cr^{3+}_{(aq)}$

        d)   -0.42 V

        e)

8. a) $2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$
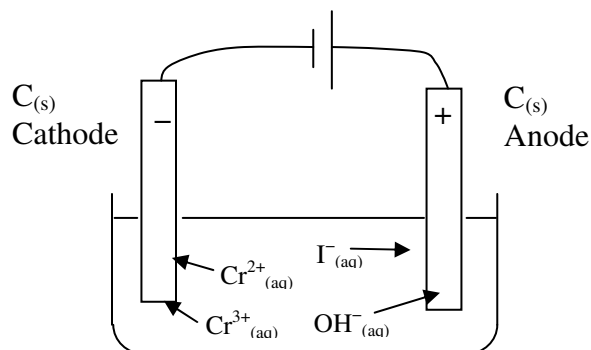
    b) $K = \dfrac{\left[CO_{2(g)}\right]^2}{\left[CO_{(g)}\right]^2 \left[O_{2(g)}\right]}$

    c) According to Hess's Law, $\Delta H = -566$ kJ (the reaction is exothermic). Increasing temperature is the same as adding energy, which is a product. The system responds by consuming the additional products and shifting to **reactants** (left)

8d) Increasing total volume decreases total pressure. The system responds by trying to increase pressure. This is accomplished by shifting to the side of the equilibrium with more gas molecules (shift to **reactants**).
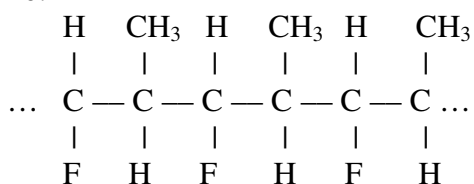
e)

	$[CO_{(g)}]$	$[O_{2(g)}]$	$[CO_{2(g)}]$
Initial	**3.30**	**3.30**	**0**
Change	-1.15	-0.575	+1.15
Equilibrium	**2.15**	2.725	1.15

K = 0.105

f) **reactants** are favoured

9.   5.6 mol/L

10.

$$\ldots \; C - C - C - C - C - C \; \ldots$$

```
     H    CH₃  H    CH₃  H    CH₃
     |    |    |    |    |    |
...  C — C — C — C — C — C ...
     |    |    |    |    |    |
     F    H    F    H    F    H
```

11.   ethanol   +   methanoic acid

$$CH_3 - CH_2 - OH \qquad\qquad H - \overset{\overset{\textstyle O}{\|}}{C} - OH$$

12. a) propan-1-ol $\xrightarrow{H_2SO_4}$ propene   +   water

$$\underset{\overset{|}{OH}}{CH_2} - CH_2 - CH_3 \qquad CH_2 = CH - CH_3 \qquad \underset{\overset{|}{H}}{H} - O$$
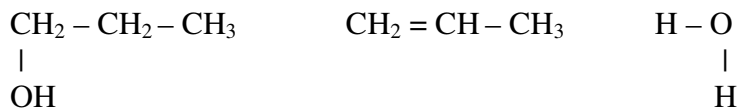
b)   butan-2-ol   + hydrogen chloride → 2-chlorobutane + water

$$\underset{\overset{|}{OH}}{CH_3 - CH} - CH_2 - CH_3 \qquad H - Cl \qquad \underset{\overset{|}{Cl}}{CH_3 - CH} - CH_2 - CH_3 \qquad \underset{\overset{|}{H}}{H} - O$$