INSTRUCTIONS TO CANDIDATES

- All questions are to be attempted. There are 20 pages of examinable material.
- Complete the examination paper in **INK**.
- Read each question carefully. Report the appropriate answer and show all relevant working in the space provided.
- The total score for this paper is 100. The possible score per page is shown in the adjacent tables.
- Each new question of the short answer section begins with a •.
- Electronic calculators, including programmable calculators, may be used. Students are warned, however, that credit may not be given, even for a correct answer, where there is insufficient evidence of the working required to obtain the solution.
- Numerical values required for any question, standard electrode reduction potentials, a Periodic Table and some useful formulas may be found on the separate data sheets.
- Pages 17, 19 and 24 are for rough working only.
• Complete the following table. H₂O is given as an example.

<table>
<thead>
<tr>
<th>Species</th>
<th>Central atom</th>
<th>Number of nonbonding pairs on central atom</th>
<th>Hybridisation of central atom</th>
<th>Geometry of molecule</th>
<th>Polarity of molecule</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>O</td>
<td>2</td>
<td>sp³</td>
<td>bent</td>
<td>polar</td>
</tr>
<tr>
<td>HCOOH</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCN</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

• The energy difference between the \( n = 3 \) state and the \( n = 2 \) state in hydrogen is \( 3.03 \times 10^{-19} \) J. What is the wavelength of light emitted when an electron moves from the \( n = 3 \) to the \( n = 2 \) state?

Answer:

• Explain the difference between the electron affinity and electronegativity of an atom.

• In terms of the quantum theory of the electron, explain why electrons involved in covalent bonds between atoms have lower energy than they do when located on the separated atom.
A mixture of 0.500 mol of NO\(_2\) and 0.500 mol of N\(_2\)O\(_4\) is allowed to reach equilibrium in a 10.0 L vessel maintained at 298 K. The equilibrium is described by the equation below. \(\Delta H^\circ = -15 \text{ kJ mol}^{-1}\) for the forward reaction.

\[
2\text{NO}_2(g) \rightleftharpoons \text{N}_2\text{O}_4(g) \quad K_c = 1.2 \times 10^2 \text{ M}^{-1}
\]

Show that the system is at equilibrium when the concentration of NO\(_2\) is 0.023 M.

Discuss the effect an increase in temperature, at constant volume, would have on the concentration of NO\(_2\).

State with a brief reason whether the concentration of NO\(_2\) is increased, decreased, or unchanged when argon gas (0.2 mol) is injected while the temperature and volume remain constant.
The final step in the industrial production of urea, \((\text{NH}_2)_2\text{CO}\), is:

\[
\text{CO}_2(g) + 2\text{NH}_3(g) \rightarrow \text{H}_2\text{O}(g) + (\text{NH}_2)_2\text{CO(s)} \quad \Delta H^\circ = -90.1 \text{ kJ mol}^{-1}
\]

Using the following data, calculate the standard enthalpy of formation of solid urea.

\[
\begin{align*}
4\text{NH}_3(g) + 3\text{O}_2(g) & \rightarrow 6\text{H}_2\text{O}(g) + 2\text{N}_2(g) \quad \Delta H^\circ = -1267.2 \text{ kJ mol}^{-1} \\
\text{C(s)} + \text{O}_2(g) & \rightarrow \text{CO}_2(g) \quad \Delta H^\circ = -393.5 \text{ kJ mol}^{-1} \\
2\text{H}_2(g) + \text{O}_2(g) & \rightarrow 2\text{H}_2\text{O}(g) \quad \Delta H^\circ = -483.6 \text{ kJ mol}^{-1}
\end{align*}
\]

The formation of urea in the industrial process is only spontaneous below 821 °C. What is the value of the entropy change \(\Delta S^\circ\) (in J K\(^{-1}\) mol\(^{-1}\)) for the reaction?

\[
\Delta S^\circ = \quad \text{Mark(s) = 6}
\]

Rationalise the sign of \(\Delta S^\circ\) in terms of the physical states of the reactants and products.
• A key step in the metabolism of glucose for energy is the isomerism of glucose-6-phosphate (G6P) to fructose-6-phosphate (F6P);

\[
\begin{align*}
\text{G6P} & \quad \text{↔} \quad \text{F6P}
\end{align*}
\]

At 298 K, the equilibrium constant for the isomerisation is 0.510. Calculate \( \Delta G^\circ \) at 298 K.

Answer:


Answer:

In which direction will the reaction shift in order to establish equilibrium? Why?

• The specific heat capacity of water is 4.18 J g\(^{-1}\) K\(^{-1}\) and the specific heat capacity of copper is 0.39 J g\(^{-1}\) K\(^{-1}\). If the same amount of energy were applied to a 1.0 mol sample of each substance, both initially at 25 °C, which substance would get hotter? Show all working.

Answer:
### The active ingredient in aspirin is the monoprotic acid, acetylsalicylic acid (HC₉H₇O₄) that has a $K_a$ of $3.3 \times 10^{-4}$ M at 25 °C. What is the pH of a solution obtained when a tablet containing 200 mg of acetylsalicylic acid is dissolved in 125 mL of water?

**Answer:**

### A standard test for the presence of chloride ion in water involves the appearance of a precipitate of AgCl upon addition of 1 mL of AgNO₃ (0.03 M) to 100 mL of the water sample. What is the minimum concentration of Cl⁻ detectable by this method? $K_{sp}$ (AgCl) = $1.8 \times 10^{-10}$ M².

**Answer:**

### The fission of U-235 is initiated by the absorption of one neutron. One pathway results in the formation of I-137, two neutrons and one other isotope. What is the other isotope?

**Answer:**
- Oral rehydration therapy (ORT) is a simple low-cost treatment that replaces fluid and electrolytes lost by sufferers of diarrhoea. To make the solution for ORT, 3.5 g NaCl, 2.9 g sodium citrate (which contains 1 citrate$^{3-}$ and 3 Na$^{+}$ ions and has a molar mass of 258 g mol$^{-1}$), 1.5 g KCl and 20.0 g glucose (C$_6$H$_{12}$O$_6$) are dissolved in water to make 1.0 L of solution. What is the osmotic pressure (in mmHg) of this solution at body temperature (37 °C)?

### Marks

4

---

<table>
<thead>
<tr>
<th>Answer:</th>
</tr>
</thead>
</table>

This pressure is about the same as the osmotic pressure of blood. The calorie content of the solution can be increased by adding either more glucose or a polymer of glucose. Which would be preferable? Give a brief reason.

---

- Draw all of the geometric isomers for the complex ion [CoI$_2$(NH$_3$)$_4$]$^+$. Label each isomer with its systematic name.

### Marks

2
• Calculate the standard free-energy change for the following reaction at 298 K.

\[ 2\text{Au(s)} + 3\text{Ca}^{2+} (1.0 \text{ M}) \rightarrow 2\text{Au}^{3+} (1.0 \text{ M}) + 3\text{Ca(s)} \]

Answer:

Complete and balance the following equation for the reaction between iron(II) ions and permanganate ions in an acidic solution.

\[ \text{Fe}^{2+} + \text{MnO}_4^- \rightarrow \text{Fe}^{3+} + \text{Mn}^{2+} \]

Answer:

• What is the value of the equilibrium constant for the following reaction at 298 K?

\[ 2\text{Fe}^{3+} (\text{aq}) + \text{Sn(s)} \rightleftharpoons \text{Sn}^{2+} (\text{aq}) + 2\text{Fe}^{2+} (\text{aq}) \]

Answer:
• If a medical procedure calls for 1.0 mg of $^{128}\text{Ba}$, how much isotope would be required to be able to use it exactly one week later? The half life of $^{128}\text{Ba}$ is 2.43 days.

Answer:

• Will a precipitate form when 200 mL of 0.0040 M $\text{BaCl}_2$ is added to 600 mL of 0.0080 M $\text{K}_2\text{SO}_4$? Show all working. $K_{sp}$ for $\text{BaSO}_4 = 1.1 \times 10^{-10}$ M$^2$.

Answer:

• Complete the following table.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Systematic name</th>
</tr>
</thead>
<tbody>
<tr>
<td>$[\text{Pt(NH}_3)_4]\text{Cl}_2$</td>
<td></td>
</tr>
<tr>
<td>$\text{NaH}_2\text{PO}_4$</td>
<td>lead(II) phosphate</td>
</tr>
<tr>
<td></td>
<td>magnesium hydroxide-2-water</td>
</tr>
</tbody>
</table>
Consider the results of the following set of experiments studying the rate of the reaction of nitric oxide with hydrogen at 1280 °C.

\[
2\text{NO(g)} + 2\text{H}_2(g) \rightarrow \text{N}_2(g) + 2\text{H}_2\text{O(g)}
\]

<table>
<thead>
<tr>
<th>Experiment #</th>
<th>[NO] / M</th>
<th>[H\textsubscript{2}] / M</th>
<th>Initial Rate / M s\textsuperscript{-1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.0 \times 10^{-3}</td>
<td>2.0 \times 10^{-3}</td>
<td>1.3 \times 10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>1.0 \times 10^{-2}</td>
<td>2.0 \times 10^{-3}</td>
<td>5.2 \times 10^{-5}</td>
</tr>
<tr>
<td>3</td>
<td>1.0 \times 10^{-2}</td>
<td>4.0 \times 10^{-3}</td>
<td>1.0 \times 10^{-4}</td>
</tr>
</tbody>
</table>

Write the rate law expression.

\[
\text{Rate} =
\]

Calculate the rate constant, \( k \). Include units in your answer.

\[
k =
\]

What is the rate of the reaction when [NO] is 1.2 \times 10^{-2} M and [H\textsubscript{2}] is 6.0 \times 10^{-3} M?

\[
\text{Rate} =
\]
• Describe how hydrophilic and hydrophobic colloids are stabilised in water.
**CHEM1612 - CHEMISTRY 1B (PHARMACY)**

**DATA SHEET**

*Physical constants*

Avogadro constant, \( N_A = 6.022 \times 10^{23} \text{ mol}^{-1} \)
Faraday constant, \( F = 96485 \text{ C mol}^{-1} \)
Planck constant, \( h = 6.626 \times 10^{-34} \text{ J s} \)
Speed of light in vacuum, \( c = 2.998 \times 10^8 \text{ m s}^{-1} \)
Rydberg constant, \( E_R = 2.18 \times 10^{-18} \text{ J} \)
Boltzmann constant, \( k_B = 1.381 \times 10^{-23} \text{ J K}^{-1} \)
Gas constant, \( R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1} \)
\[ = 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1} \]
Charge of electron, \( e = 1.602 \times 10^{-19} \text{ C} \)
Mass of electron, \( m_e = 9.1094 \times 10^{-31} \text{ kg} \)
Mass of proton, \( m_p = 1.6726 \times 10^{-27} \text{ kg} \)
Mass of neutron, \( m_n = 1.6749 \times 10^{-27} \text{ kg} \)

*Properties of matter*

Volume of 1 mole of ideal gas at 1 atm and 25 °C = 24.5 L
Volume of 1 mole of ideal gas at 1 atm and 0 °C = 22.4 L
Density of water at 298 K = 0.997 g cm\(^{-3}\)

*Conversion factors*

1 atm = 760 mmHg = 101.3 kPa
0 °C = 273 K
1 L = 10\(^{-3}\) m\(^3\)
1 Å = 10\(^{-10}\) m
1 eV = 1.602 \times 10^{-19} \text{ J}
1 Ci = 3.70 \times 10^{10} \text{ Bq}
1 Hz = 1 s\(^{-1}\)

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Prefix</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>10(^{-3})</td>
<td>milli</td>
<td>m</td>
</tr>
<tr>
<td>10(^{-6})</td>
<td>micro</td>
<td>µ</td>
</tr>
<tr>
<td>10(^{-9})</td>
<td>nano</td>
<td>n</td>
</tr>
<tr>
<td>10(^{-12})</td>
<td>pico</td>
<td>p</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multiple</th>
<th>Prefix</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>10(^3)</td>
<td>kilo</td>
<td>k</td>
</tr>
<tr>
<td>10(^6)</td>
<td>mega</td>
<td>M</td>
</tr>
<tr>
<td>10(^9)</td>
<td>giga</td>
<td>G</td>
</tr>
</tbody>
</table>
### Standard Reduction Potentials, $E^\circ$

<table>
<thead>
<tr>
<th>Reaction</th>
<th>$E^\circ / \text{V}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co$^{3+}$(aq) + e$^-$ → Co$^{2+}$(aq)</td>
<td>+1.82</td>
</tr>
<tr>
<td>Ce$^{4+}$(aq) + e$^-$ → Ce$^{3+}$(aq)</td>
<td>+1.72</td>
</tr>
<tr>
<td>Au$^{3+}$(aq) + 3e$^-$ → Au(s)</td>
<td>+1.50</td>
</tr>
<tr>
<td>Cl$_2$ + 2e$^-$ → 2Cl$^-$ (aq)</td>
<td>+1.36</td>
</tr>
<tr>
<td>O$_2$ + 4H$^+$ (aq) + 4e$^-$ → 2H$_2$O</td>
<td>+1.23</td>
</tr>
<tr>
<td>MnO$_2$(s) + 4H$^+$ (aq) + e$^-$ → Mn$^{3+}$ + 2H$_2$O</td>
<td>+0.96</td>
</tr>
<tr>
<td>Pd$^{2+}$(aq) + 2e$^-$ → Pd(s)</td>
<td>+0.92</td>
</tr>
<tr>
<td>Ag$^+$ (aq) + e$^-$ → Ag(s)</td>
<td>+0.80</td>
</tr>
<tr>
<td>Fe$^{3+}$(aq) + e$^-$ → Fe$^{2+}$(aq)</td>
<td>+0.77</td>
</tr>
<tr>
<td>Cu$^+$ (aq) + e$^-$ → Cu(s)</td>
<td>+0.53</td>
</tr>
<tr>
<td>Cu$^{2+}$(aq) + 2e$^-$ → Cu(s)</td>
<td>+0.34</td>
</tr>
<tr>
<td>Sn$^{4+}$(aq) + 2e$^-$ → Sn$^{2+}$(aq)</td>
<td>+0.15</td>
</tr>
<tr>
<td>2H$^+$ (aq) + 2e$^-$ → H$_2$(g)</td>
<td>0 (by definition)</td>
</tr>
<tr>
<td>Fe$^{3+}$(aq) + 3e$^-$ → Fe(s)</td>
<td>−0.04</td>
</tr>
<tr>
<td>Pb$^{2+}$(aq) + 2e$^-$ → Pb(s)</td>
<td>−0.13</td>
</tr>
<tr>
<td>Sn$^{2+}$(aq) + 2e$^-$ → Sn(s)</td>
<td>−0.14</td>
</tr>
<tr>
<td>Ni$^{2+}$(aq) + 2e$^-$ → Ni(s)</td>
<td>−0.24</td>
</tr>
<tr>
<td>Fe$^{2+}$(aq) + 2e$^-$ → Fe(s)</td>
<td>−0.44</td>
</tr>
<tr>
<td>Cr$^{3+}$(aq) + 3e$^-$ → Cr(s)</td>
<td>−0.74</td>
</tr>
<tr>
<td>Zn$^{2+}$(aq) + 2e$^-$ → Zn(s)</td>
<td>−0.76</td>
</tr>
<tr>
<td>2H$_2$O + 2e$^-$ → H$_2$(g) + 2OH$^-$ (aq)</td>
<td>−0.83</td>
</tr>
<tr>
<td>Cr$^{2+}$(aq) + 2e$^-$ → Cr(s)</td>
<td>−0.89</td>
</tr>
<tr>
<td>Al$^{3+}$(aq) + 3e$^-$ → Al(s)</td>
<td>−1.68</td>
</tr>
<tr>
<td>Mg$^{2+}$(aq) + 2e$^-$ → Mg(s)</td>
<td>−2.36</td>
</tr>
<tr>
<td>Na$^+$ (aq) + e$^-$ → Na(s)</td>
<td>−2.71</td>
</tr>
<tr>
<td>Ca$^{2+}$(aq) + 2e$^-$ → Ca(s)</td>
<td>−2.87</td>
</tr>
<tr>
<td>Li$^+$ (aq) + e$^-$ → Li(s)</td>
<td>−3.04</td>
</tr>
</tbody>
</table>
### Quantum Chemistry

\[
E = h\nu = \frac{hc}{\lambda}
\]

\[
\lambda = \frac{h}{mv}
\]

\[
4.5k_B T = \frac{hc}{\lambda}
\]

\[
E = Z^2E_R (1/n^2)
\]

\[
\Delta x \cdot \Delta (mv) \geq \frac{h}{4\pi}
\]

### Radioactivity

\[
t_{\frac{1}{2}} = \ln 2 / \lambda
\]

\[
A = \lambda N
\]

\[
\ln \left( \frac{N_0}{N_0} \right) = \lambda t
\]

\[1^{14}\text{C age} = 8033 \ln(A_0/A_t)\]

### Acids and Bases

\[
pK_w = pH + pOH = 14.00
\]

\[
pK_w = pK_a + pK_b = 14.00
\]

\[
\text{pH} = pK_a + \log \left( \frac{[A^-]}{[HA]} \right)
\]

### Gas Laws

\[
PV = nRT
\]

\[
(P + n^2a/V^2)(V - nb) = nRT
\]

### Colligative properties

\[
\pi = cRT
\]

\[
P_{\text{solution}} = X_{\text{solvent}} \times P^o_{\text{solvent}}
\]

\[
p = kc
\]

\[
\Delta T_I = K_Bm
\]

\[
\Delta T_b = K_Bm
\]

### Kinetics

\[
t_{\frac{1}{2}} = \ln 2 / k
\]

\[
k = Ae^{-E_a/RT}
\]

\[
\ln [A] = \ln [A_0] - kt
\]

\[
\ln \frac{k_2}{k_1} = \frac{E_a}{RT} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)
\]

### Electrochemistry

\[
\Delta G^o = -nFE^o
\]

**Moles of e^- = It/F**

\[
E = E^o - (RT/nF) \times 2.303 \log Q
\]

\[
E = E^o - (RT/nF) \times \ln Q
\]

\[
E^o = (RT/nF) \times 2.303 \log K
\]

\[
E = (RT/nF) \times \ln K
\]

\[
E = E^o - \frac{0.0592}{n} \log Q \text{ (at 25 °C)}
\]

### Thermodynamics & Equilibrium

\[
\Delta G^o = \Delta H^o - T\Delta S^o
\]

\[
\Delta G = \Delta G^o + RT \ln Q
\]

\[
\Delta G^o = -RT \ln K
\]

\[
K_p = K_c (RT)^{\Delta n}
\]

### Polymers

\[
R_g = \sqrt{\frac{\frac{1}{6} n l_i^2}{n}}
\]

### Mathematics

If \( ax^2 + bx + c = 0 \), then

\[
x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}
\]

\[
\ln x = 2.303 \log x
\]