The problem sheets on the proceeding pages are designed to show your understanding of some of the areas covered in the lecture courses. Each week, you should attempt all of the questions prior to the tutorial. The answers will be provided on the ‘Resources’ page, accessed via WebCT or the unit area on the First Year Chemistry website, at the end of the week before the tutorial. These should be used to check your answers, correct minor errors and to provide you with an idea of topics which you need to build on. Your tutor will ask you at the start of the tutorial for the topics and questions to go over.

In addition, your tutor will go over a number of past examination questions from the list given on the next page. Full solutions to these questions will not be provided online until the end of the semester.

Your performance in the tutorial quizzes and in the end of semester examination will be greatly enhanced by your attendance and involvement in the tutorial sessions.

In quiz weeks, you should attempt the sample quizzes, accessed via the ‘Tutorial Quizzes’ page on WebCT or on your unit area on the First Year Chemistry website. Your tutor will cover problems with these quiz questions prior to the actual quiz.
### CHEM1109 Tutorials - Past Examination Questions

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<td>• 2003-N-6 (part (ii) only)&lt;br&gt;• 2004-N-7 (part (i) only)&lt;br&gt;• 2005-N-8</td>
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<td>• 2003-N-8 (part (iv) only)&lt;br&gt;• 2004-N-7 (part (ii) only)&lt;br&gt;• 2003-N-6 (part (i) only)&lt;br&gt;• 2004-N-8</td>
<td>• 2005-N-9&lt;br&gt;• 2005-N-10 (parts (i), (ii) and (iii))&lt;br&gt;• 2004-N-11&lt;br&gt;• 2004-N-12 (part (i) only)</td>
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There are a number of important learning resources available on your unit area on the First Year Chemistry website: http://firstyear.chem.usyd.edu.au/chem1109

Spend some time getting yourself familiar with this website and have a look at available resources, which include self help quizzes, games and calculators.

One of the most important resources is **ChemCAL**, an interactive tutorial/quiz program which covers most of the first year chemistry topics. Past students have found the program's interactive tutorials very useful. A link to ChemCAL is provided on the menu of all First Year Chemistry webpages. You log on to ChemCAL using your course code (‘1109’) as username, and *helium* as the password. (Note that none of the marks you receive in the various ChemCAL quizzes are ever recorded or assessed, and multiple attempts are OK!)

**Work through the ChemCAL module "Chemical Energy and Calorimetry".**

1. Use the ‘Food Energy Calculator’ to calculate your daily energy requirements based on your 'basal metabolism rate' (BMR) and the energy you use for activities each day:


2. A watt is a measure of power: the rate of energy change in J s\(^{-1}\).
   
   (a) Calculate the number of watts in a kilowatt-hour.
   
   (b) An adult human radiates heat to the surroundings at about the same rate as a 100-watt electric bulb. What is the total heat radiated (in kJ) to the surroundings by an adult in 24 hours?

3. Perform the following calculations, giving the final answer to the appropriate number of significant figures. **If you do not know how to use significant figures, work through W5 in the Laboratory Handbook.**

   (a) Three students are 2 m, 1.5 m and 1.6 m tall. What is their average height?
   
   (b) NaCl has a molar mass of 36.458 g mol\(^{-1}\). How many moles are there in 25 g?
   
   (c) This quantity of NaCl is added to 200.0 mL of water. What is the concentration?

4. Urea, \((NH_2)_2CO\) (6.006 g) is burnt in excess oxygen to yield liquid water, \(CO_2(g)\) and \(N_2(g)\). 63.4 kJ of heat was liberated at 298 K and 101.3 kPa

   \[\Delta H_{298}^{\circ}\text{, in kJ mol}^{-1}: \quad CO_2(g) \quad -393; \quad H_2O(l) \quad -285\]

   (a) Write an equation for the combustion.
   
   (b) Calculate the heat energy released (in kJ) when 1.00 mol of urea is completely burnt.
   
   (c) Use your answer to (b) and the data above to calculate the enthalpy of formation of solid urea at 298 K and 101.3 kPa.

   The number of significant figures in your answer should always reflect those in the data provided. The sign (+ or -) of your answer is very important.
1. It takes 78.2 J to raise the temperature of 45.6 g of lead by 13.3 °C. What are the specific and molar heat capacities of lead?

2. In a coffee cup calorimeter, 100 mL of 1.0 M HCl and 100 mL of 1.0 M NaOH are mixed. Before mixing, both solutions are at 24.6 °C. After the reaction, the temperature is 31.3 °C. Assuming no density change, and that the heat capacity of the solution is that of water, calculate the standard enthalpy of neutralisation of H^+(aq) by OH (aq). (Assume a perfect calorimeter where no heat is lost to the surroundings.)

3. A 0.0100 mol sample of propane was placed into a bomb calorimeter with excess oxygen and ignited. The equation for the reaction is:

   \[
   \text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l})
   \]

   The initial temperature of the calorimeter was 25.000 °C and its total heat capacity was 96.5 kJ °C⁻¹. The reaction raised the temperature of the calorimeter to 27.828 °C. Calculate the energy (in kJ) liberated by the combustion of the propane.

4. During exercise, fat molecules react with water (hydrolyse) to form a group of compounds called fatty acids. These fatty acids are then converted to carbon dioxide and water releasing energy to power the muscles. A typical human fatty acid is palmitic acid, \( \text{CH}_3(\text{CH}_2)_{14}\text{COOH} \).

   (a) Write a balanced equation for the complete oxidation of palmitic acid producing \( \text{CO}_2(\text{g}) \) and \( \text{H}_2\text{O}(\text{l}) \).

   (b) The direct combustion of palmitic acid in a calorimeter yields the same products as in the body together with the production of 9980 kJ of heat per mole of palmitic acid. Using the data at the foot of the page, calculate the standard enthalpy of formation of palmitic acid?

   (c) Carbohydrates yield about 17 kJ g⁻¹ of energy in the body. Calculate the equivalent energy value of fat using palmitic acid as the example.

5. Methyl stearate, \( \text{CH}_3(\text{CH}_2)_{16}\text{COOCH}_3 \), is a significant component of some biodiesel formulations. Its heat of formation is −945.6 kJ mol⁻¹.

   (a) Calculate its heat of combustion using the data at the foot of the page.

   (b) Convert the heat of combustion into the nett calorific value, in kJ g⁻¹, and compare this with the value for conventional diesel of 42.5 kJ g⁻¹.

6. Calcium carbide reacts with water as follows:

   \[
   \text{CaC}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_2\text{H}_2(\text{g}) + \text{Ca(OH)}_2(\text{s})
   \]

   Use the following data to calculate the enthalpy change when calcium carbide (10.0 g) reacts with excess water at 298 K.

   \[
   \Delta H^\circ_{298}, \text{in kJ mol}^{-1}: \quad \text{CaC}_2(\text{s}) = -60; \quad \text{H}_2\text{O}(\text{l}) = -285; \quad \text{C}_2\text{H}_2(\text{g}) = +227;
   \]

   \[
   \text{Ca(OH)}_2(\text{s}) = -986; \quad \text{CO}_2(\text{g}) = -393.5
   \]
1. The main energy-producing reaction in all oxygen-using living organisms is oxidation of glucose:

\[ C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) \]

(a) Using the data below, calculate the standard enthalpy of combustion of glucose.

\[ \Delta_f H^\circ_{298}, \text{ in kJ mol}^{-1}: \quad C_6H_{12}O_6(s) -1285; \quad CO_2(g) -393; \quad H_2O(l) -285 \]

(b) Calculate the standard free energy change for this reaction, \( \Delta G^\circ (298 \text{ K}) \), given \( \Delta S^\circ = 181 \text{ J K}^{-1} \text{ mol}^{-1} \) for this reaction at 298 K.

(c) In a living cell, energy from glucose combustion is partly used to synthesise the energy-storage molecule, ATP:

\[ \text{ADP} + P_i \rightarrow \text{ATP} \quad \Delta G^\circ = +30.5 \text{ kJ mol}^{-1} \]

Assuming the efficiency of ATP synthesis is 41%, calculate the number of mole of ATP produced per mole of glucose oxidised.

(d) In the above equation for the synthesis of ATP, what is the significance of the positive sign of \( \Delta G^\circ \)?

2. For a particular chemical reaction, \( \Delta H = 5.5 \text{ kJ} \) and \( \Delta S = 25 \text{ J K}^{-1} \) and do not vary greatly with temperature. Under what temperature condition(s) is the reaction spontaneous?

3. What are the signs of \( \Delta G \), \( \Delta H \) and \( \Delta S \) for the freezing of liquid water at \(-10 \degree \text{C}\)?

4. Determine the volume occupied by 4.0 g of \( O_2 \) gas at STP. (STP is ‘standard temperature and pressure’ corresponding to 1 atm and 0 \degree \text{C})

5. A piece of solid carbon dioxide, with a mass of 7.8 g, is placed inside a sealed 1.2 L container of air at a pressure of 740 mmHg. What would be the partial pressure of carbon dioxide and the total pressure inside the container after all the carbon dioxide has sublimed (turned to gas)?

6. A sample of nitrogen gas was collected over water at 20 \degree \text{C} and a total pressure of 1.00 atm. The vapour pressure of water under these conditions is 17.5 mmHg. If a total volume of 645 mL was collected, what mass of nitrogen was contained in the sample?
1. Ammonium carbamate (NH₂CO₂NH₄) is a salt of carbamic acid that is found in the blood and urine of mammals. At 250 °C, \( K_c = 1.58 \times 10^{-8} \) for the following equilibrium:

\[
\text{NH}_2\text{CO}_2\text{NH}_4(s) \rightleftharpoons 2\text{NH}_3(g) + \text{CO}_2(g)
\]

If 7.80 g of NH₂CO₂NH₄ is introduced into a 0.500 L evacuated container, what is the total pressure inside the container at equilibrium at 250 °C?

2. Water is oxidised to give hydrogen peroxide according to the reaction below.

\[
\text{H}_2\text{O}(g) + \frac{1}{2}\text{O}_2(g) \rightleftharpoons \text{H}_2\text{O}_2(g)
\]

(a) Using the data below, calculate \( \Delta G^\circ \) at 600 K for this reaction.

\[
\begin{align*}
\text{H}_2(g) + \text{O}_2(g) & \rightleftharpoons \text{H}_2\text{O}_2(g) \quad K_p = 2.3 \times 10^6 \text{ atm}^{-1} \text{ at 600 K} \\
2\text{H}_2(g) + \text{O}_2(g) & \rightleftharpoons 2\text{H}_2\text{O}(g) \quad K_p = 1.8 \times 10^{37} \text{ atm}^{-1} \text{ at 600 K}
\end{align*}
\]

(b) Calculate the equilibrium constant \( K_c \) for the reaction.

(c) At 600 K, the entropy change, \( \Delta S^\circ \), for the reaction is +60 J K⁻¹ mol⁻¹. Using this value and the value for \( \Delta G^\circ \) from (a), calculate the enthalpy change, \( \Delta H^\circ \), at 600 K.

(d) What is the effect on \([\text{H}_2\text{O}_2]\) if the system is subjected to the following changes.

(i) The volume of the container is decreased.
(ii) The temperature is increased.
(iii) A solid catalyst is added at constant temperature and volume.

3. The equilibrium constant, \( K_p \), for the reaction below is 11.5 at 600 K.

\[
\text{PCl}_5(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g)
\]

2.450 g of PCl₅ is placed in an evacuated 500 mL bulb, which is heated to 600 K.

(a) What would be the initial pressure of PCl₅(g) before it dissociates?
(b) What is the partial pressure of PCl₃(g) at equilibrium?
(c) What is the total pressure in the bulb at equilibrium?
(d) What is the degree of dissociation of PCl₅(g) at equilibrium?

**Hint for part (b)**
As \( K_p \) is not very small, you cannot assume that the amount of product formed is small compared to the amount of starting material and you will need to solve the quadratic formula.
1. A solution prepared by dissolving 0.30 g of polyacrylamide in 100 mL of water has an osmotic pressure of $8.3 \times 10^{-5}$ atm at 25 $^\circ$C. What molar concentration of glucose would be isotonic with this solution?

2. Rank the following solutions in order of increasing osmotic pressure:

   - 1 M $\text{H}_2\text{SO}_4$
   - 1 M $\text{HCl}$
   - 0.5 M glucose
   - 0.5 M $\text{CaCl}_2$
   - 0.5 M $\text{NaCl}$

3. A solution is prepared by dissolving 1.00 mg of an unknown protein in 1.00 mL of water. The osmotic pressure of the solution was measured to be 95 Pa at 25 $^\circ$C. What is the molecular weight of the protein?

4. Sea water from the Gulf of Mexico contains approximately 59 g salt per 1000 g water. Given the cryoscopic constant of water is 1.86 K kg mol$^{-1}$, at what temperature would this water freeze?

5. Lactic acid ($\text{C}_3\text{H}_6\text{O}_3$), a monoprotic acid, is a waste product that accumulates in muscle tissue during exertion, leading to pain ("cramp") and a feeling of fatigue. In a 0.100 M aqueous solution, lactic acid is 3.7% dissociated. If the equilibrium concentration of $\text{H}^+$ ion is $x$ mol L$^{-1}$, write the equilibrium expression for $K_a$ in terms of $x$ and thus work out the equilibrium concentrations, the value of pH and $K_a$ for lactic acid.

6. Give the concentration of hydrogen ions present and hence calculate the pH of each of the following water solutions:

   (a) hydrochloric acid (0.14 M)
   (b) nitric acid (0.0025 M)
   (c) sodium hydroxide (0.048 M)
   (d) barium hydroxide ($3.7 \times 10^{-3}$ M)

7. In a titration experiment, 50.0 mL of 0.100 M $\text{HCl}$ is reacted with $\text{NaOH}$.

   (a) Calculate the pH when the following quantities of 0.100 M $\text{NaOH}$ have been added:

      (i) 0.0 mL (initial pH)
      (ii) 25.0 mL
      (iii) 45.0 mL
      (iv) 50.0 mL
      (v) 55.0 mL
      (vi) 75.0 mL

   (b) Using the calculated values, plot the pH curve for the titration.
1. The pKₐ of acetic acid is 4.76. Calculate the pH of the following solutions:
   (a) 0.2 M acetic acid
   (b) 0.2 M sodium acetate
   (c) A buffer that is 0.2 M in acetic acid and 0.2 M in sodium acetate

2. Histidine is an amino acid of importance in maintaining the catalytic activity of proteolytic (protein cleaving) enzymes.

   ![Histidine structure]

   The pK₁, pK₂ and pK₃ values for histidine are 1.81, 6.05 and 9.15. These values correspond to the α-COOH group, the imidazole ring and the α-NH₃⁺ group respectively.

   In a buffer solution where pH = pKₐ, the concentration of the acid and its conjugate base are equal. Give the constitutional formulas of the acid species and its conjugate base associated with the following pKₐ values.
   (a) 1.81   (b) 6.05   (c) 9.15

3. A buffer at physiological pH of 7.40 is required. What quantities of 0.10 M HPO₄²⁻ and H₂PO₄⁻ are required to make 1.0 L of this buffer? (pKₐ (H₂PO₄⁻) = 7.20)

4. In a titration experiment, 50.0 mL of 0.100 M acetic acid (pKₐ = 4.76) is reacted with NaOH.

   (a) Calculate the pH when the following quantities of 0.100 M NaOH have been added:

   (i) 0.0 mL (initial pH)
   (ii) 25.0 mL
   (iii) 45.0 mL
   (iv) 50.0 mL
   (v) 55.0 mL
   (vi) 75.0 mL

   (b) Using the calculated values, plot the pH curve for the titration.
   (c) Compare your curve with that obtained for Q7 on Problem Sheet 5.
CHEM1109 Problem Sheet 7 (Week 8)

1. Classify the solutions formed from the following salts as acidic, basic or neutral.
   (a) KNO₃
   (b) FeCl₃
   (c) Ca(OH)₂
   (d) (NH₄)₂SO₄
   (e) NaN₃
   (f) BaCl₂

2. The $K_{sp}$ of Ca₃(PO₄)₂ = 1.3 × 10⁻³² M⁵.
   (a) Calculate the solubility of Ca₃(PO₄)₂ in water in mol L⁻¹ and g L⁻¹.
   (b) Calculate the molar solubility of Ca₃(PO₄)₂ in 0.20 M Na₃PO₄ solution.

3. Will a precipitate occur if a 0.01 M Ag⁺ solution is mixed with an equal volume of 0.01 M sulfuric acid? $K_{sp}$ (Ag₂SO₄) = 2 × 10⁻⁵ M³

4. Give the oxidation number of the underlined element in the following.
   (a) KMnO₄
   (b) SO₄²⁻
   (c) Na₂O₂
   (d) MgH₂
   (e) NH₄⁺
   (f) BrF₃
   (g) [Ni(NH₃)₆]²⁺
   (h) K₄[Fe(CN)₆]

5. $K_{stab}$ of [Zn(NH₃)₄]²⁺ is 8 × 10⁻⁸ M⁻⁴. What is the molarity of Zn²⁺(aq) ions in the solution made by adding water to zinc nitrate (0.10 mol) and ammonia (3.0 mol) so that the final volume of solution is 1.5 L?

6. Human haemoglobin has a molecular weight of 6.45 × 10⁴, a concentration in blood of 15.0 g per 100 mL and contains 3.4 g of iron per kg. It reacts with oxygen to form a complex that contains 4 molecules of oxygen per molecule of haemoglobin.
   (a) Calculate the volume of oxygen per 100 mL of fully oxygenated blood at 311 K and 101.3 kPa.
   (b) Calculate the number of iron atoms in each molecule of haemoglobin.
   (c) Magnetic studies show that the haemoglobin molecule contains 4 unpaired electrons per iron atom. What is the oxidation state of the iron?
1. Complete the table below by giving the name of each compound and indicating whether stereoisomers of each complex ion are possible.

<table>
<thead>
<tr>
<th>species</th>
<th>name</th>
<th>stereoisomerism of complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) [Co(NH$_3$)$_5$Cl]Cl$_2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) [Fe(H$_2$O)$_4$Br$_2$]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) K[Ag(CN)$_2$]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. How long must a current of 2.0 A be applied to a solution containing Au$^{3+}$ to deposit 1.0 g of gold?

3. Use the table of reduction potentials to predict whether, to any significant extent
   (a) Mg(s) will displace Pb$^{2+}$ from aqueous solution
   (b) Tin will react and dissolve in 1 M HCl
   (c) SO$_4^{2-}$ will oxidise Sn$^{2+}$ to Sn$^{4+}$ in acidic solution
   (d) MnO$_4^-$ (aq) will oxidise H$_2$O$_2$(aq) to O$_2$(g) in acidic solution

4. An electrochemical cell is composed of these two half cells (at 298 K):
   \[
   \begin{align*}
   \text{Fe}^{3+} + e^- & \rightarrow \text{Fe}^{2+} \quad E^\circ = 0.77 \text{ V} \\
   \text{Sn}^{2+} + 2e^- & \rightarrow \text{Sn} \quad E^\circ = -0.13 \text{ V}
   \end{align*}
   \]
   (a) What reactions occur at the anode and at the cathode of the cell?
   (b) What is the overall cell reaction?
   (c) What is the standard voltage of this cell?
   (d) What is the equilibrium constant for this reaction?
   (e) What is the value of $\Delta G^\circ$ for this reaction?
   (f) What is the voltage of the cell once equilibrium is reached?
   (g) If the concentration of the iron ions is maintained at 1 M but the concentration of Sn$^{2+}$ is adjusted to 0.001 M, what is the voltage of the cell?
1. Nicotinamide adenine dinucleotide (NADH), a cofactor in many biochemical reactions, is a strong reducing agent in water solution:

\[
\text{NADH} + \text{H}^+ \rightleftharpoons \text{NAD}^+ + 2\text{H}^+ + 2e^- \quad E^\circ = 0.527 \text{ V}
\]

Calculate the value of \(E^\circ\) (potential at the biological standard state of pH = 7.0) for this half cell at 298 K.

2. The pyruvate ion (Pv\(^-\)) is reduced to the lactate ion (PvH\(_2\)\(^-\)) at pH 7 in half cell below.

\[
Pv^- + 2\text{H}^+ + 2e^- \rightleftharpoons \text{PvH}_2^- \quad E^\circ' = -0.185 \text{ V}
\]

Assume this half cell is combined with the NAD ion half cell of Q1 at pH 7.

(a) What is the overall cell reaction?
(b) What is the voltage of this cell at pH 7?
(c) What is the equilibrium constant for this reaction at 298 K and pH 7?
(d) What is the value of \(\Delta G^\circ\) for this reaction at 298 K?
(e) Would the EMF of the cell increase, decrease or remain unchanged if:
   (i) the pH of the NADH half-cell were reduced to 6.0?
   (ii) [NADH] were reduced to 0.1 M?

3. Typical concentrations of Na\(^+\) and K\(^+\) in the intracellular and extracellular fluid are given below. Estimate the potential difference between the inside and outside of a cell.

- Na\(^+\): 142 mM extracellular, 10 mM intracellular
- K\(^+\): 4 mM extracellular, 140 mM intracellular

4. One of the key reactions in the formation of acid rain and in the industrial production of nitric acid is the reaction of nitric oxide with oxygen:

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

The following data were obtained at constant temperature.

<table>
<thead>
<tr>
<th>experiment number</th>
<th>initial concentrations (mol L(^{-1}))</th>
<th>initial reaction rate (mol L(^{-1}) s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[O(_2)]</td>
<td>[NO]</td>
</tr>
<tr>
<td>1</td>
<td>1.10 \times 10^{-2}</td>
<td>1.30 \times 10^{-2}</td>
</tr>
<tr>
<td>2</td>
<td>2.20 \times 10^{-2}</td>
<td>1.30 \times 10^{-2}</td>
</tr>
<tr>
<td>3</td>
<td>1.10 \times 10^{-2}</td>
<td>2.60 \times 10^{-2}</td>
</tr>
<tr>
<td>4</td>
<td>3.30 \times 10^{-2}</td>
<td>1.30 \times 10^{-2}</td>
</tr>
</tbody>
</table>

(a) Deduce the rate equation and find the value of the rate constant for this reaction.
(b) If the initial rate of consumption of oxygen was 1 \times 10^{-3} mol L\(^{-1}\) s\(^{-1}\), what is the initial rate of formation of NO\(_2\)(g)?
CHEM1109 Problem Sheet 10 (Week 13)

1. The half life at 20 °C for the first order decomposition of N\(_2\)O\(_5\)(g) is 6.00 \times 10^4 s. Calculate the rate constant at this temperature.

2. Using the data below for the hydrolysis of an antibiotic in a patient, calculate the activation energy, \(E_a\), and the "A" factor for the hydrolysis of this antibiotic.

<table>
<thead>
<tr>
<th>Temperature / °C</th>
<th>Rate constant, (k) / L mol(^{-1}) s(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>0.208</td>
</tr>
<tr>
<td>0</td>
<td>0.248</td>
</tr>
</tbody>
</table>

3. For the reaction 2O\(_3\) \rightarrow 3O\(_2\) a suggested mechanism is:

\[
\begin{align*}
O_3 & \underset{k_{-1}}{\rightleftharpoons} O_2 + O & \text{fast} \\
O_3 + O & \underset{k_2}{\rightarrow} 2O_2 & \text{slow}
\end{align*}
\]

(a) On the basis of this mechanism, write the rate equation for this reaction.
(b) What is the molecularity of the rate determining step?

4. For each of the following groups of isotopes, which is likely to be the most stable? What decay modes are the unstable ones most likely to undergo, and what product(s) would be formed?

(a) \(^{19}\)Ne, \(^{20}\)Ne, \(^{23}\)Ne
(b) \(^{58}\)Ni, \(^{59}\)Ni, \(^{66}\)Ni

5. Using the decay data of plutonium isotopes below, rank the isotopes in order of their likely harm to living organisms.

\[
\begin{align*}
^{238\ 94}\text{Pu} & \rightarrow \alpha (5.50 \text{ MeV}) + \gamma (0.044 \text{ MeV}) + \frac{234}{92}\text{U} \quad (t_{1/2} = 87.7 \text{ years}) \\
^{239\ 94}\text{Pu} & \rightarrow \alpha (5.16 \text{ MeV}) + \gamma (0.374 \text{ MeV}) + \frac{235}{92}\text{U} \quad (t_{1/2} = 2.41 \times 10^4 \text{ years}) \\
^{240\ 94}\text{Pu} & \rightarrow \alpha (5.26 \text{ MeV}) + \gamma (0.104 \text{ MeV}) + \frac{236}{92}\text{U} \quad (t_{1/2} = 6537 \text{ years}) \\
^{241\ 94}\text{Pu} & \rightarrow \beta^- (4.85 \text{ MeV}) + \gamma (0.149 \text{ MeV}) + \frac{242}{95}\text{Am} \quad (t_{1/2} = 14.4 \text{ years}) \\
^{242\ 94}\text{Pu} & \rightarrow \alpha (4.98 \text{ MeV}) + \gamma (0.104 \text{ MeV}) + \frac{238}{92}\text{U} \quad (t_{1/2} = 3.76 \times 10^5 \text{ years})
\end{align*}
\]

6. Positron-emission tomography (PET) may be used to image soft tissue and relies on emission of a positron from a radioactive isotope. \(^{15}\)O labelled water may be used. What isotope is formed by positron emission from \(^{15}\)O?
7. The function of the thyroid gland may be monitored using $^{131}\text{I}$, which decays by $\beta$ emission with a rate constant of 0.086 $\text{day}^{-1}$. How long does it take for the concentration of $^{131}\text{I}$ to fall to 10% of its original value?

8. Complete the following table by indicating the state (solid, liquid or gas) of the dispersed phase and the dispersing medium and the name of the colloid system of the following examples.

<table>
<thead>
<tr>
<th>Example</th>
<th>Dispersed phase</th>
<th>Dispersing system</th>
<th>Name of colloid system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaving cream</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fog</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toothpaste</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Styrofoam</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Explain the main structural feature(s) of a cell membrane.

10. Explain why $\text{Mg}^{2+}$ gives rise to ‘hard’ water, while $\text{Na}^+$ does not.