Answers to Practice Test Questions 6
Metals of Groups 1 and 2

1. *Only one answer required for each blank; "/" indicates possible choices*

(a) lustre / malleability / ductility / good conductor of heat / good conductor of electricity
(Must be a property that nonmetals do not have!)

(b) hydrogen (H)

(c) beryllium (Be)

(d) violet

(e) beryllium (Be)

(f) radium (Ra)

(g) sodium (Na)

(h) hydrogen (H_2)

(i) lithium (Li^+)

(j) liquid

2.

(a) $2Cs(s) + Cl_2(g) \rightarrow 2CsCl(s)$

(b) $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

or $2Na(s) + 2H_2O(l) \rightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g)$

(c) $BaO(s) + 2H^+(aq) \rightarrow Ba^{2+}(aq) + H_2O(l)$

(d) $2Ca(s) + O_2(g) \rightarrow 2CaO(s)$

(e) $Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$

or $Ca(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2(g)$

(f) $6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$

(g) $Ca(s) + Br_2(l) \rightarrow CaBr_2(s)$

(h) $2Na(s) + Br_2(l) \rightarrow 2NaBr(s)$

(i) $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g)$

(j) $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

(k) $2K(s) + F_2(g) \rightarrow 2KF(s)$

(l) $4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$

(m) $3Ca(s) + N_2(g) \rightarrow Ca_3N_2(s)$

(n) *reasonable options: metal + acid; alkali metal + water; aluminium + strong base; etc.*

3.

(a) $2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$

(b) $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) + Cl_2(g)$

or $2Cl^-(aq) + 2H_2O(l) \rightarrow 2OH^-(aq) + H_2(g) + Cl_2(g)$

(c) electrolysis

(d) Water is present in the production of sodium hydroxide. No water is present in the production of sodium metal.

When pure NaCl(l) is electrolyzed, the best electron acceptors are the Na^+ cations, so Na metal is produced.

When water is present in addition to NaCl, the best electron acceptors are the H^+ cations, so hydrogen gas is produced and the Na^+ cations do not react. As H^+ cations are consumed, more H^+ and OH^- are produced from the water.

Recall Le Châtelier's principle and what happens when a product is removed from a system at equilibrium such as $H_2O(l) \Leftrightarrow H^+(aq) + OH^-(aq)$.

This results in a build-up of OH^- anions which are pumped away along with the spectator Na^+ cations as NaOH(aq).

Alternately, you could argue that the abundant water molecules accept the electrons, generating hydroxide ions and hydrogen gas. In this case, you must argue that water is a better electron acceptor than Na^+ *(which is valid given the standard reduction potentials of the two species).*

4.

(a) An electric current is necessary for electrolysis.
Ionic solids cannot conduct electric currents.

(b) i. $2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$

ii. The Na(l) and Cl_2(g) would react to give back NaCl(l).

(c) i. $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) + Cl_2(g)$

or $2Cl^-(aq) + 2H_2O(l) \rightarrow 2OH^-(aq) + H_2(g) + Cl_2(g)$

ii. The NaOH(aq) and Cl_2(g) would react to give NaOCl(aq) and NaCl(aq).

5.

(a) Both metals react with nitrogen gas to give nitrides.

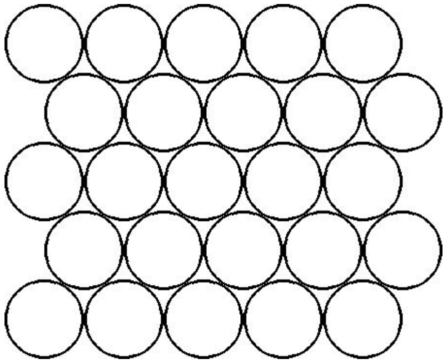
This is not the only acceptable answer, but is the main one discussed in CHEM 1000.

(b) Li^+ and Mg^{2+} have comparable charge densities.

Since lithium is much smaller than sodium, the charge density of Li^+ is significantly higher than that of Na^+ (and closer to that of Mg^{2+}). As a result, ionic compounds containing Li^+ can have similar properties to those containing Mg^{2+}.

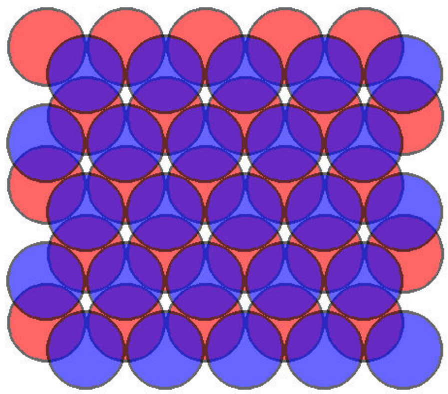
6.

(a)



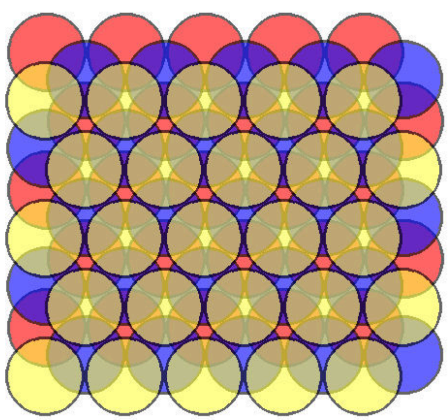
This diagram represents one layer of atoms in a closest packed lattice. Each circle represents one atom.

(b) Hexagonal closest packed lattices contain two alternating layers of closest packed atoms. This layering is sometimes described as ABABAB and looks like this:



Below the red layer there is another blue layer then another red layer then another blue layer the another red layer and so on…

Cubic closest packed lattices contain three alternating layers of closest packed atoms. This layering is sometimes described as ABCABC and looks like this:



Below the red layer there is another yellow layer then another blue layer then another red layer then another yellow layer then another blue layer then another red layer and so on…

7. *Any one of the following:*

- tends to form covalent bonds (BeH_2, $BeCl_2$, etc.)
- does not react (spontaneously) with oxygen in air
- does not react (spontaneously) with water
- forms an amphoteric oxide (BeO is both acid and base)
- its oxide (BeO) doesn't react with air
- the hydrated cation ($[Be(OH_2)_4]^{2+}$) is more acidic

8.

(a) Beryllium chloride is not an ionic compound (unlike $MgCl_2$ or $CaCl_2$). For an ionic compound to exist, both the cation and anion must be relatively stable. A beryllium cation (Be^{2+}) would only have one shell of electrons (electron configuration $1s^2$). As such, it would be very small (smaller than helium!) – too small to fully stabilize a +2 charge. So, $BeCl_2$ is a covalent compound while $MgCl_2$ and $CaCl_2$ are ionic.

(b) The chemistry of beryllium and aluminium are often similar. This is an example of a diagonal relationship.

9. Perform flame tests.

- Na^+ in NaCl burns yellow.
- Li^+ in $LiNO_3$ burns red.

10.

(a) hydrogen (H_2)

(b) $M(s) + 2HCl(aq) \rightarrow MCl_2(aq) + H_2(g)$

or $M(s) + 2H^+(aq) \rightarrow M^{2+}(aq) + H_2(g)$

(c)	M(s)	+	2 HCl(aq)	→	MCl_2(aq)	+	H_2(g)
M	??? g/mol		36.4606 g/mol		??? g/mol		2.0158 g/mol
m_{inital}	100 mg						
$c_{initial}$			1 mol/L				
V			1 L				62 mL
P							1.00 bar
T							298.15 K
$n_{initial}$	0.0025 mol		1 mol		0 mol		0 mol
n_{change}	-0.0025 mol		-0.0050 mol		+0.0025 mol		+0.0025 mol
n_{final}	0 mol		1 mol		0.0025 mol		0.0025 mol

Step 1: Write a balanced chemical equation for the reaction

see part (b)

Step 2: Organize all known information

see above; values in grey are not necessary for this calculation

Step 3: Calculate moles of H_2 produced (n_{final})

$PV = nRT$

$$n_{H_2-final} = \frac{PV}{RT} = \frac{(100kPa)(62mL)}{\left(8.3145\frac{Pa\cdot m^3}{mol\cdot K}\right)(298.15K)} \times \frac{1L}{1000mL} \times \frac{1000Pa}{1kPa} \times \frac{1m^3}{1000L} = 0.0025mol$$

Step 4: Identify the limiting reagent

Since 0.0025 mol H_2 are produced, 0.0025 mol M and 0.0050 mol HCl must be consumed. Since one of these two species must be the limiting reagent and it clearly isn't the HCl (which has $n_{initial}$ = 1 mol), the metal must be the limiting reagent.

Step 5: Calculate the initial moles of unknown metal ($n_{initial}$)

Since the limiting reagent runs out, n_{final} for the metal must be 0 moles.

Therefore, $n_{initial}$ for the unkown metal must be 0.0025 mol.

Step 6: Calculate the molar mass of the metal (M)

$$M_M = \frac{m_{initial}}{n_{initial}} = \frac{100mg}{0.0025mol} \times \frac{1g}{1000mg} = 40\,\frac{g}{mol}$$

Step 7: Identify the unknown metal

The alkaline earth metal with the molar mass closest to 40 g/mol is calcium (Ca)

Step 8: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

The molar mass of the unknown metal was a good match for one alkaline earth metal.

(d) Several good suggestions were made, including:

- flame test (if negative, test for reactivity with water to identify Mg vs. Be)
- measure density by displacing an unreactive liquid (e.g. oil)

11.

(a) $2NaOH(aq) + Cl_2(g) \rightarrow NaOCl(aq) + NaCl(aq) + H_2O(l)$

(b) **Step 1: Calculate the number of moles of NaOCl in any volume of bleach**

An easy volume to work with is 100. mL since we know that 100. mL contains 4.5 g NaOCl.

$$n_{NaOCl} = 4.5g \times \frac{1mol}{74.4419g} = 0.060mol$$

Step 2: Divide the number of moles of NaOCl by the chosen volume of bleach

$$c_{NaOCl} = \frac{n_{NaOCl}}{V} = \frac{0.060\ mol}{100mL} \times \frac{1000mL}{1L} = 0.60\frac{mol}{L}$$

Step 3: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

(c)	2 NaOH(aq)	+ $Cl_2(g)$	→ NaOCl(aq)	+ NaCl(aq)	+ $H_2O(l)$
M	39.9971 g/mol	70.9054 g/mol	74.4419 g/mol	58.4425 g/mol	18.0152 g/mol
V			4.0 L		
c_{final}			0.60 mol/L		
$n_{initial}$	4.8 mol	excess	0 mol	0 mol	a lot
n_{change}	-4.8 mol	-2.4 mol	+2.4 mol	+2.4 mol	+2.4 mol
n_{final}	0 mol	some	2.4 mol	2.4 mol	a lot

Step 1: Write a balanced chemical equation for the reaction

see part (a)

Step 2: Organize all known information

see above; values in grey are not necessary for this calculation; M_{NaOCl} was used in part (b) to find c_{NaOCl}

Step 3: Calculate moles of NaOCl that must be produced to make 4.0L bleach (n_{final})

$$n_{NaOCl-final} = 4.0L \times 0.60\frac{mol}{L} = 2.4mol$$

Step 4: : Use mole ratio to calculate moles of NaOH that must react ($n_{initial}$)

$$n_{NaOH-initial} = 2.4\ mol\ NaOCl \times \frac{2\ mol\ NaOH}{1\ mol\ NaOCl} = 4.8\ mol\ NaOH$$

Step 5: Calculate the mass of NaOH that must react ($m_{initial}$)

$$m_{NaOH-initial} = 4.8mol \times \frac{39.9971g}{1mol} = 193g = 1.9 \times 10^2 g = 0.19kg$$

Step 6: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

If you don't carry all the digits in your calculator through the whole calculation (both steps (b) and (c)), you will introduce rounding error into your final answer.

12.

(a) $2NaCl(aq) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g) + Cl_2(g)$

(b) *1 ton = 1000 kg = 1 Mg; it's easiest to solve this problem using Mg and Mmol*

	$2\ NaCl(aq)$	+	$2\ H_2O(l)$	$\rightarrow$	$2\ NaOH(aq)$	+	$H_2(g)$	+	$Cl_2(g)$
M	58.4425 g/mol		18.0152 g/mol		39.9971 g/mol		2.0158 g/mol		70.9054 g/mol
m_{final}					6×10^6 Mg				
$n_{initial}$	2×10^5 Mmol				0 Mmol				
n_{change}	-2×10^5 Mmol				$+ 2\times10^5$ Mmol				
n_{final}	0 Mmol				2×10^5 Mmol				
$m_{initial}$	9×10^6 Mg								

Step 1: Write a balanced chemical equation for the reaction

see part (a)

Step 2: Organize all known information

see above; values in grey are not necessary for this calculation

Step 3: Calculate moles of NaOH produced (n_{final})

$$n_{NaOH-final} = 6 \times 10^6 Mg \times \frac{1mol}{39.9971g} = 2 \times 10^5 Mmol$$

Step 4: Use mole ratio to calculate moles of NaCl required for reaction ($n_{initial}$)

$$n_{NaCl-initial} = 2 \times 10^5\ Mmol\ NaOH \times \frac{2\ mol\ NaCl}{2\ mol\ NaOH} = 2 \times 10^5\ Mmol\ NaCl$$

Step 5: Calculate masses of NaCl required for reaction ($m_{initial}$)

$$m_{NaCl-initial} = 2 \times 10^5\ Mmol\ NaCl \times \frac{58.4425g}{1\ mol} = 9 \times 10^6 Mg\ NaCl$$

Therefore, it requires 9 million tons of NaCl to make 6 million tons of NaOH.

Step 6: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

The two masses are of the same order of magnitude. Since Cl has a higher molar mass than O+H, it makes sense that a higher mass of NaCl is required (since there is a 1 : 1 mole ratio of NaCl : NaOH).