S0. Style Questions

For each of the three styles *style-1, style-2,* and *style-3*, provide a statement describing the styles as well as the differences and similarities between them by addressing each of the following topics:

40%	**Describe the aroma, appearance, flavor, and mouthfeel of each style as in the BJCP Style Guidelines.**
25%	**Identify at least one aspect of the ingredients (malts, hops, water chemistry) or background information (history, fermentation techniques and conditions, or serving methods) that distinguishes each style.**
10%	**For each of the styles, name at least one classic commercial example as listed in the BJCP Style Guidelines.**
25%	**Describe the similarities and differences between the three styles.**

* Describe most important elements of AAFM first and in most detail. (e.g., mention toast, light roast and chocolate notes first when describing the aroma of a robust porter, then hop notes).

* Remember

Aroma: Malt (base, specialty), hops, yeast (esters, phenols), other (e.g., alcohol, spices, herbs, oxidative notes).

Appearance: Color, clarity, head (color, texture, retention).

Flavor: Malt (base, specialty), hops (bitter, flavor), fermentation characteristics (esters, phenols, alcohol, etc.), balance, finish/aftertaste, other (e.g., spices, herbs, oxidative notes).

Mouthfeel: Body, Carbonation, Mouth texture (e.g., Creaminess), Warmth, Other (e.g., minerals, resins, physical heat or cooling).

* For the "Identify" portion of the question briefly identify at least 2 distinctive features from any of the following categories: Ingredients, vital statistics, brewing or aging process, history, country or region of origin or serving methods *as described in the BJCP Guidelines or maybe the Brewers Association "style" books*. (e.g., "German Pils malt base, lager, invented in 1898 in Munich" for a Munich Helles).

* For the "classic example" portion, name just one classic commercial example mentioned in the BJCP Guidelines. This is important since it's 10% of your score and it's usually just a few words. Be as clear as possible (e.g., "Spaten Premium Lager" not just "Spaten").

* Describe at least 2 similarities and two differences for each of the three styles compared to get at least 6 factoids. (e.g., "All are golden in color and clear. Helles and Dortmunder Export are both lagers, although Cream Ale can be brewed as a lager. Dortmunder is higher in alcohol, with a more minerally finish and drier flavor. Cream Ale is American, Helles and Dort are German. Cream Ale is brewed with a significant proportion of corn and has fruity esters in aroma and flavor. Cream Ale and Dortmunder have similar ABV ranges, but Dort can go up to 6% ABV.")

Odds of Being Tested on a Particular Beer Style

Chances	Style	Odds %
10	Oktoberfest/Märzen	4.07
9	Strong Scotch Ale	3.66
7	American Stout	2.85
7	Dry Stout	2.85
7	Foreign Extra Stout	2.85
7	Weizen/Weissbier	2.85
6	Munich Dunkel	2.44
6	Robust Porter	2.44
6	Scottish Light 60/-	2.44
6	Straight (Unblended) Lambic	2.44
6	Traditional Bock	2.44
5	American PaleAle	2.03
5	Brown Porter	2.03
5	English Barleywine	2.03
5	German Pilsner (Pils)	2.03
5	Mild	2.03
5	Munich Helles	2.03
5	North German Altbier	2.03
5	Scottish Heavy 70/-	2.03
4	American BrownAle	1.63
4	California Common Beer	1.63
4	Doppelbock	1.63
4	Düsseldorf Altbier	1.63
4	Schwarzbier	1.63
4	Sweet Stout	1.63
3	American Barleywine	1.22
3	American Wheat or Rye Beer	1.22
3	Belgian Blond Ale	1.22
3	Belgian Dark Strong Ale	1.22
3	Belgian Pale Ale	1.22
3	Berliner Weisse	1.22
3	Bohemian Pilsener	1.22
3	Eisbock	1.22
3	Imperial IPA	1.22
3	Irish Red Ale	1.22
3	Maibock/Helles Bock	1.22
3	Scottish Export 80/	1.22
3	Southern English Brown Ale	1.22
3	Special/Best/Premium Bitter	1.22
3	Standard American Lager	1.22
3	Standard/Ordinary Bitter	1.22
3	Weizenbock	1.22
3	Witbier	1.22
2	Premium American Lager	0.81
2	American AmberAle	0.81
2	Baltic Porter	0.81
2	Belgian Dubbel	0.81
2	Belgian Tripel	0.81
2	Bière de Garde	0.81
2	Classic American Pilsner	0.81
2	Cream Ale	0.81
2	Dunkelweizen	0.81
2	Extra Special/Strong Bitter (English Pale Ale)	0.81
2	Flanders Red Ale	0.81
2	Gueuze	0.81
2	Imperial Stout	0.81
2	Kölsch	0.81
2	Lite American Lager	0.81
2	Northern English Brown Ale	0.81
2	Oatmeal Stout	0.81
2	Old Ale	0.81
2	Roggenbier (German Rye Beer)	0.81
2	Saison	0.81
2	Vienna Lager	0.81
1	American IPA	0.41
1	Belgian Golden Strong Ale	0.41
1	Blonde Ale	0.41
1	Classic Rauchbier	0.41
1	Dark American Lager	0.41
1	Dortmunder Export	0.41

1	English IPA	0.41
1	Flanders Bown Ale/Oud Bruin	0.41
1	Fruit Lambic	0.41

Technical Question T1. "Off Flavors"

Describe and discuss the following beer characteristics. What causes them and how are they avoided and controlled? Are they ever appropriate and if so, in what beer styles? (three will be given)

30%	Describe each characteristic.
40%	Identify the causes and controls for each characteristic.
30%	Identify appropriate/ inappropriate styles.

The choices will be drawn from: a) cloudiness, b) buttery, c) low head retention, d) astringency, e) phenolic, f) light body, g) fruitiness, h) sourness, i) cooked corn, j) bitterness, k) cardboard, l) sherry-like, m) acetaldehyde, n) alcoholic.

T3. What are body and mouthfeel? Explain how the brewer controls body and mouthfeel in his/her beer. Cover the following topics:

50%	Describe each characteristic.
50%	Identify the causes and controls for both.

Question T3. "Body and Mouthfeel" Sample Answer.

1) Body

Describe: A sub-characteristic of Mouthfeel (see below).

2) Mouthfeel

Describe: The tactile character of beer, how it "feels" in your mouth. Determined by Alcohol, Astringency, Body, Creaminess, Carbonation, and other physical sensations.

Element	Describe/Cause	Control
Alcohol	Solventy, hot, burning, numbing, warming. **Cause:** Alcohol attacking pain receptor nerves. Closely related to alcohol flavor. Ethanol produces "smoother" heat than fusel oils, which are "harsh" or hot. All alcohols are produced by yeast as fermentation products. Fusels are caused by high temperature fermentation or unhealthy or stressed yeast.	* Reduce O.G. * Ferment at cooler temperature (reduces fusels). * Properly aerate wort. * Pitch sufficient yeast for style (at least 1-1.5 quarts of starter for most styles, more for strong ales and lagers). * Age beer to allow higher alcohols to degrade.
Astringency	Puckering, numbing or harsh bitterness. Phenolics (esp. polyphenols = tannins) acting on nerves. **Causes:** From husks due to excessively fine grain crush, sparge water > 5.8 pH, sparge water >170 °F, or husks in boiling wort. From barrel-aging in oak. From fruit pits, stems or husks in fruit beers, esp. if boiled/pasteurized above ~>170 °F. Hot break & trub carried into fermenter. Cold break carried into finished beer. Highly alkaline water. Bacterial infection. Yeast autolysis.	* Don't overmill grain. * Don't oversparge/rinse grains (below SG 1.008). * Don't expose grains to temp. above ~>170 °F * Avoid high alkaline/sulfate water. * Rolling boil for at least 1 h. to promote hot break. * Longer aging time for barrel-aged beer. * Remove pits/stems/husks from fruit before adding to beer & don't expose to temp. above ~>170 °F.
Body	Subjective measure of palate fullness or viscosity - how "rich" or "filling" the beer feels in your mouth. Primarily determined by the concentration of dextrins & med.-length proteins in finished beer. Gums and highly caramelized sugars also play a role. Non-flocculent yeast or suspended starch particles contribute to sensation of body. **Causes:** Wort gravity. Yeast/starch haze. Mash temperature: low mash temp. (140 - 150 °F) promotes Beta-Amylase activity, prod. thinner, more fermentable wort. Excessively long Protein rest (122 - 133 °F for 1+ hr.) breaks down body-forming proteins. Bacterial/Wild yeast infection can metabolize dextrins, reducing body.	**To increase:** Increase grain bill. Increase dextrin and protein levels in mash. Toasted & caramel/crystal malts have higher levels of non-fermentable sugars. Higher protein malts (e.g., wheat, rye, oat) or unmalted protein-rich grains (e.g., flaked rye or oats). Don't filter or fine beer. Don't cold condition for long periods of time. Choose non-flocculent yeast strain. Mash at higher temp. (162 - 167 °F). Skip protein rest. Skip beta-glucan rest. Don't filter, or use a larger filter. Practice good sanitation.
Carbonation	"Prickly," "stinging" or "tingling" **Cause:** CO_2 activating trigeminal nerve. Can affect perception of flavor and body due to "drying" and "lightening" effects on flavor and body. Can aid in perception of aroma due to volatile compounds in beer being "scrubbed out" of	To increase: Control CO_2 levels during packaging. Don't agitate beer excessively (removes CO_2).

	solution by escaping CO_2.	
Creaminess	"Creaminess" or "oiliness" opposite of "Crispness" Physical texture and mouth-coating characteristic. Related to body.	To increase: add high-protein or "oily" grains to beer (e.g., oats). Don't filter or fine. Choose non-flocculent yeast strain. Proper protein/beta-glucan rest (at ~110-120 °F for 20 minutes) to get proteins/gums into beer.

Mouthfeel

Describe: Mouthfeel is the tactile character of food or drink -how it "feels" in your mouth and how it stimulates the sensory nerves of your mouth and tongue other than the tastebuds. Mouthfeel of beer is determined by levels of Astringency, Body (Viscosity), Carbonation, Creaminess (Mouth Texture), Warmth (Alcohol) and Other Palate Sensations (e.g., temperature and chemical warming or cooling sensations).

Astringency

Detected in: Mouthfeel.

Described As: Astringent, drying, harsh, numbing, puckering. Always a fault.

Typical Origins: Grains, wood aging, fruits or spices.

Discussion: Caused by Phenols (esp. polyphenols = tannins) acting on nerves and physically drying tissues. Polyphenols are naturally found in grain husks and other tough plant material. Imparted to beer from grain husks, but also excessive hop levels, fruit/spice/herb/veg. additions, Barrel-aging Hot break & trub carried into fermenter. Cold break carried into finished beer. Highly alkaline water. Bacterial infection. Yeast autolysis.

To Avoid: * Don't overmill grain. Don't oversparge/rinse grains. Keep sparge water at or below 5.8 pH. Don't collect runoff below 0.008 S.G. Don't expose grains to temperatures above 168 °F. * Rolling boil of at least 1 hour to promote hot break. Proper hot & cold break separation. * Age wood-aged beer for longer period of time. * Remove pits, stems and husks from fruit before adding to beer. Don't expose fruit, herbs or spices to temperatures above 168 °F. * Avoid alkaline (i.e., high carbonate) or high sulfate (above ~200 ppm) water. * Observe proper sanitation to avoid bacterial infection. * Don't leave beer on yeast cake for more than 1 month to avoid autolysis.

When is Astringency Appropriate?: High levels of astringency are never appropriate. Very low levels of astringency are acceptable in wood-aged beers, beers made with a high proportion of dark malt or roasted grains, and beers made with fruits or spices which are high in tannins (e.g., cranberries, cinnamon).

Body (Viscosity) - Remember: Focus mostly on this section!

Detected in: Mouthfeel.

Described As: Ranges from very thin (bland, characterless, diluted, empty, flavorless, watery) to very full (chewy, cloying, filling, satiating, unctuous).

Typical Origins: Grain.

Discussion: A subjective measure of palate fullness or viscosity - how "rich" or "filling" the beer feels in your mouth. Body is primarily determined by the concentration of dextrins, oligosaccharides & medium-length proteins in finished beer. Gums and highly caramelized sugars also play a role. Non-flocculent yeast or suspended starch particles contribute to sensation of body.

To Increase: Increase wort gravity. Use malts adjuncts with more dextrins (e.g., toasted, caramel/crystal malts) Use higher protein malts (e.g., wheat, rye, oats) or unmalted protein-rich grains (e.g., flaked rye or oats). Skip protein/beta-glucan rests. Don't filter or fine beer. Don't cold condition for long periods of time. Choose non-flocculent yeast strain. Mash at higher temp. (162 - 167 °F). Practice good sanitation.

To Reduce: Reduce wort gravity. Use fully fermentable sugar adjuncts. low mash temp. (140 - 150 °F) promotes Beta-Amylase activity, prod. thinner, more fermentable wort. Protein rest (122 - 133 °F) - esp. a long protein rest. Beta-glucan rest (110 °F) - esp. a long rest breaks. Bacterial/Wild yeast infection can metabolize dextrins. Filtration through a 1 micron or smaller filter will remove dextrins and proteins.

When is Body Appropriate?: Body is an inherent part of any liquid, so all beers have body. High alcohol, malt-focused beers can have very full body (e.g., doppelbock, Russian imperial stout, barleywines), while light American-style lagers, especially low-calorie or low-carbohydrate "lite" lagers, will have thin body. Some varieties of sour beers, where microflora have consumed most of the available starches, will also have thin body (e.g., Berlinerweisse, lambics).

Carbonation

Detected in: Mouthfeel.

Described As: Drying, effervescent, lively, lightening, prickly, stinging or tingling. Low carbonation can be described as being flat or lifeless. High carbonation can be described as gassy. Small bubbles are generally due to bottle conditioning, larger bubbles might be due to force carbonation. Carbonation affects perception of Creaminess and is also the driving force behind head formation.

Typical Origins: Yeast.

Describe: Carbon dioxide is produced by yeast during fermentation, accounting for about 50% of metabolic products. Carbon dioxide is forced into solution under pressure, traditionally occurring when beer was bottled or packaged in sealed casks. Since the 1900s, brewers have also for force-carbonated bottled or kegged beer. Kegged beer is also forced from the tank using carbon dioxide.

Homebrewers typically get carbon dioxide into their beer by bottle-conditioning, by adding priming sugar or fresh or partially fermented wort to their raw beer just before packaging, at the rate of ½ to ¾ cup of priming sugar (or equivalent, like dry malt extract) per 5 gallons. (Also see Question T9: Kräusening). Some commercial breweries bottle condition their beers as well, notably some producers of German wheat beer beers and Belgian strong ales.

Carbon dioxide is detected as a prickliness or effervescence because it activates the trigeminal nerve (the nerve responsible for sensation in the face, which has branches which terminate in the mouth and tongue).

In addition to its effects on mouthfeel, high levels of carbon dioxide can indirectly affect other sensory aspects:

Aroma: Escaping carbon dioxide and bursting bubbles formed by carbon dioxide help carry volatile aroma compounds out of solution, thus increasing beer aroma.

Appearance: Carbon dioxide bubbles are visible in the glass unless the beer is flat. Escaping carbon dioxide is the main force behind head formation, so it directly affects head formation and retention.

Flavor and Mouthfeel: High carbonation levels can affect perception of flavor and body due to “drying” and “lightening” effects on flavor and body. Conversely, low carbon dioxide levels can make flavors seem sweeter and more intense, and make body seem fuller.

To Increase: If bottle conditioning, increase priming sugar during packaging. If necessary, add yeast or yeast nutrient at packaging to quickly obtain proper CO_2 levels. Cap firmly to keep gas from escaping. If force carbonating choose proper CO_2 level for style. Don’t agitate beer excessively (removes CO_2).

To Reduce: Reduce priming sugar, kräusening or CO_2 pressure. Allow beer to stand or off-gas before consuming.

When is Carbonation Appropriate?: Most beers have some degree of carbonation (see table below). Unblended lambics and other Belgian sour beers have very little to no carbonation. Cask-conditioned English, Irish and Scottish beers, notably bitters and English pale ales, are cask-conditioned, resulting in low carbonation, but they are not truly flat. German wheat beers and bottle-conditioned Belgian strong ales can have very high levels of carbonation, as can gueuze and fruit lambics.

High CO2 = 3-4 vol = German Wheat Beers, Berlinerweiss, Gueuze, Fruit Lambic, Belgian Strong Ales
Med. High CO2 = 2.5-3.0 = Lagers, Cream Ale, California Common, Kolsch, Altbier, American Ales, Belgian Strong ales
Med CO2 = 2-2.5 vol = Eisbock, Bohemian Pils, Doppelbock, American Wheat/Rye, Foreign/Extra Stout, Altbier, American ales, Rauchbier, Schwarzbier, Witbier, Sweet Stout, Belgian Pale Ale, Flanders Brown, Flanders Red, Robust Porter, IPA
Med-Low CO2 = <2 vol. Robust porter, English ales, strong American or English ales, Stouts, IPA, Scottish Ale, Strong Scottish Ale.
Low CO2 = 0.75-1.5 = Any cask style ale (e.g., English bitter, Scottish ales)
V. Low = <0.75 = Straight Lambic

Creaminess (AKA Mouth Texture, Stickiness, Oiliness)

Detected in: Mouthfeel.

Described As: Creamy, oily, mouth-coating, rich, slippery, smooth. In some ways, “creaminess” it is the opposite of “crisp” mouth texture.

Typical Origins: Grain.

Discussion: Creaminess is the degree to which the liquid clings to, and coats, the mouth. It is closely related to body and carbonation levels. To some extent creaminess is affected by presence of the same ingredients which aid head retention and formation - short chain proteins and carbohydrates (e.g., dextrins, oligosaccharides, beta-glucans). Perception of creaminess can also be affected by sub-threshold levels of diacetyl, which are detected only as slickness or richness in mouthfeel and by use of grains or other materials which are naturally oily (e.g., oats).

To Increase: * Protein rest to break down proteins. Beta-glucan rest to break down gums. Higher temperature mash which promotes formation of dextrins. * Use grains which are naturally gummy and/or oily (e.g., oats). * Smaller bubble size in carbonation (i.e., bottle-conditioning vs. forced carbonation). Nitrogen dispense promotes smaller bubbles which increases creaminess. * Sub-threshold levels of diacetyl.

To Decrease: * Extremely long protein or beta-glucan rest which degrades those compounds to an excessive degree. Lower temperature mash which promotes the formation of simple sugars. * Reduced diacetyl levels. * Larger bubble size (i.e., forced carbonation).

When is Creaminess Appropriate?: Creamy texture might be encountered in any full-bodied beer, especially one which includes oats or oat malt as part of the grist (e.g., oatmeal stout).

Warmth (Alcohol)

Detected in: Mouthfeel.

Described As: Burning, hot, harsh, numbing, prickly, solventy, smooth or warming. Can be felt in the nose, throat and chest as well as the mouth.

Typical Origins: Yeast.

Discussion: Alcohol warm is caused by Ethanol or Fusel Alcohols attacking pain receptor nerves in the mouth. Ethanol causes “smooth” warming sensations. Higher alcohols produce hot, harsh, solventy feelings.

To Increase: Increase wort gravity. Mash at lower temperature (143-149 °F). Add fermentable sugars. Ferment at higher temperatures.

To Reduce: Reduce wort gravity. Mash at higher temperature range (149-158 °F). Ferment at cooler temperature (to reduce higher alcohols) Age beer to allow higher alcohols to degrade.

When is Alcohol Warmth Appropriate?: Any beer of 6% ABV or higher might have detectable alcohol warmth. Harsh or burning alcohol warmth is never appropriate, but smooth warming from ethanol is expected, even welcome, in strong beers.

Other Palate Sensations

Researchers into mouthfeel disagree over which flavor characteristics actually constitute mouthfeel. This section covers a wide variety of factors. For the exam, you don’t need to go into detail about any of them, just mention that they exist and possibly a type of beer particularly associated with them (e.g., resinous and IPA).

Aroma/Flavor Sensations: Some sensations which primarily affect aroma and flavor can also affect mouthfeel, especially at high levels. See Alkaline, Alpha Acids, Chlorophenol, Fat Oil or Hydrocarbon, Leathery, Metallic, Mineral, Oxidation, Phenols, Smoky, Solventy/solventy esters, Sour, Spicy, Sweet, Umami, Vicinal Diketones (VDK) and Yeasty.

Pain/Numbness

Detected in: Mouthfeel.

Described As: Burning, cooling, painful, numbing.

Typical Origins: Yeast.

Discussion: Certain chemicals can physically affect the mouth by fooling, numbing or burning nerve endings. Most of these are phenolic compounds (see Chlorophenols, Phenols and Spicy), but there are exceptions. Burning or numbing compounds found in beer can include capsicum which causes chemical burning and chlorophenols which can cause numbing (although they are seldom encountered in high enough levels to do so in beer). Wintergreen - methyl salicylate - can give the illusion of cooling.

To Control or Avoid: See Chlorophenols, Phenols and Spicy.

When is Pain or Numbness Appropriate?: Unpleasant levels of pain or numbness are never appropriate. Low levels of pain or numbness associated with capsicum or wintergreen might be found in spice beers.

Powdery

Detected in: Mouthfeel.

Described As: Chalky, dusty cushion, dusty cushion, grainy, gritty, irritating, minerally, particulate, particulate matter, scratchy, silicate-like, siliceous.

Typical Origins: Process/technical faults, contamination.

Discussion: Powdery mouthfeel is caused by suspended solid materials in the beer. This fault is rarely encountered, since solid materials tend to precipitate quickly. It is occasionally encountered in cheaply made German hefeweizens where trub is added at bottling to add yeast character and turbidity. High levels of minerals in beer can also impart a powdery, minerally mouthfeel (see Alkaline or Mineral).

To Control: * Reduce mineral additions to water. * Properly filter beer. Make sure that material added to the conditioning tank (e.g., hop pellet particles, spices) doesn't get into the packaged beer.

When is Powdery Mouthfeel Appropriate?: Never.

Resinous

Detected in: Mouthfeel.

Described As: Mouth-coating or lingering hop bitterness.

Typical Origins: Hops.

Discussion: High levels of hop resins dissolved in beer can cling to the teeth and mouth as alcohol and water in the beer evaporates. Resinous mouthfeel is associated with extremely high levels of hop bitterness and is accentuated by high levels of sulfates in water.

To Control: Adjust hopping rates as appropriate for the style. Control mineral additions as appropriate for the style.

When is Resinous Mouthfeel Appropriate?: Harsh resinous aftertaste is never welcome. Pleasant lingering bitterness is expected in highly hopped beers, like American IPA and barleywines.

Temperature (Warming)

Detected in: Mouthfeel.

Described As: Cellar temperature, cold, cool, hot, freezing, refrigerator temperature, room temperature, tepid, warm.

Typical Origins: Serving temperature.

Typical Concentrations in Beer: n/a.

Perception Threshold: ?.

Beer Flavor Wheel Number: n/a.

Discussion: In addition to being a basic mouthfeel sensation, the temperature at which beer is served affects psychological sensations of how "refreshing" or "drinkable" a beer is.

Serving temperature also affects other sensory perceptions. Cooler temperatures increase the volume of carbon dioxide which can be dissolved in beer, reduces the rate at which volatile aroma compounds escape from solution (thus reducing overall aroma) and suppresses perception of malt and yeast-derived flavors. Indirectly, this can affect perception of body, making the beer seem thinner-bodied, crisper and cleaner than it might otherwise be.

Conversely warmer serving temperatures (above ~55 °F) increase perception of malt and yeast-derived flavors, which in turn affects perception of body, possibly making the beer seem fuller-bodied, creamier and less crisp. Lower carbon dioxide absorption also makes beer served too warm go flat faster.

To Control: * Serve beer at the proper serving temperature for the style, typically 40-45 °F for lagers, 55 °F for ales.

Technical Question T4. "Hops"

`Discuss hops, describing their characteristics, how these characteristics are extracted, and at least four distinct beer styles with which the different varieties are normally associated. Address the following topics:`

30%	**Describe hop characteristics.**
30%	**Discuss how hop characteristics are extracted.**
40%	**Identify associated beer styles.**

The Hop Plant

The hop plant (Humulus Lupus) is a *bine* (not a vine), native to the northern latitudes (35-55° latitude) of the northern hemisphere. They require long growing days and well-drained soil of 5.0-7.0 pH. They can grow to be up to 20 feet tall. They are quite vulnerable to various types of mold, so do well in drier climates. Alpha acids, responsible for hop bitterness, have a mildly bacteriostatic action on gram-positive bacteria, meaning that they have a preservative effect.

Hops are picked in late summer or early fall when the cones (technically, *strobiles*) have dried sufficiently. When picked, they should have a slightly papery texture. They are dried at warm (90-100 °F) temperatures in a kiln (traditionally, a building called an *oast),* then packed in airtight packages and kept refrigerated to prevent degradation of oils and resins. *Terroir* (growing region) has an effect on hop characteristics, due to different soil and climatic conditions.

Hop Chemistry

1. *Lupulin.* The active ingredient in hops, produced by glands within the strobiles of female plant. Lupulins appear as a powdery, sticky yellow resin.

2. Soft Resins

A. Humulones and Cohumulones. These are the source of alpha acids, which contribute bitterness to beer. In order for alpha acids to be soluble in liquid, they must be isomerized by boiling. Alpha acids constitute 3-10% of dry weight of the hop cones. Cohumulones are said to impart a harsher bitter. Alpha acid levels drop as hops age, especially if they are exposed to air or are stored at warm temperatures. Alpha acid percentage in poorly stored hops can drop by up to 60% within a year. For this reason, hops are stored cold and are packed into vacuum-sealed, oxygen barrier packages.

B. Lupulones and Colupulones. These are the source of beta acids. Beta acids don't isomerizes or contribute bitterness, but do contribute to hop aroma.

3. Essential Oils. These are volatile compounds detectable as hop flavors and aromas. They are easily lost during boiling, but can be retained by adding aroma and flavor hop additions late in the boil, as well as dry hop additions late in the fermentor or cask. Dry hopping works because essential oils can be extracted by alcohol and carbon dioxide.

A. Hydrocarbon-Based Oils: Monoterpenes & sequiterpenes. They represent about 75% of essential oils.

I. Monoterpenes.

a) Humulene has a delicate, refined flavor and oxidizes to produce spicy notes. "Noble" hops have high humulene levels.

b) *Myrcene* is more pungent, and is higher in U.S. hops. It oxidizes to produce citrusy or piney notes.

II. Sequiterpenes: Farnesene & Caryphyllene. They oxidize to compounds with "grassy" aromas.

B. Oxygen-Bearing Oils: Also called essential alcohols, they represent about 25% of essential hop oils. *Linalool* has a hoppy aroma. *Geraniol* has a floral, perfumy aroma like geraniums.

Measuring Bitterness

IBU: Hop bitterness is typically measured in non-scientific units of measurement called International Bitterness Units (IBU), or just BU (bitterness units). The lower threshold for detecting hop bitterness is about 10 IBU, the upper threshold for detecting hops is about 100 IBU, the degree of resolution is about 5 IBU (that is, the average person wouldn't be able to tell the difference between otherwise identical beers where one had 20 IBU, but the other had 18 or 23 IBU, but they would be able to do so if the beer had 15 or 25 IBU).

Beer with less than 20 IBU is considered to be lightly hopped. Beer with more than 50-60 IBU is considered to be heavily hopped.

HBU: This is a rule of thumb measurement used by some homebrewers to calculate hop bitterness. It consists of alpha acid % x ounces of hops. For example, 2 oz. of hops at 5% Alpha Acid would count as 10 HBU. HBU is a very simplified form of figuring Hop Utilization.

BU:GU Ratio: Since hop bitterness is balanced by alcoholic strength, malt bitterness, yeast character and other factors, a useful method of determining relative bitterness is by calculating the beer's BU:GU ratio. This is a subjective measurement invented by Ray Daniels, which a ratio of the beer's IBU level against the last two digits of its Original Gravity. For example, an Imperial IPA with 100 IBU, but an O.G. of 1.050 would have a BU:GU ratio of 2:1 (extremely hoppy), while a Weizenbock (20 IBU, O.G. 1.070) would have a ratio of 1:3.5 (very malty).

Hop Utilization

Sometimes called Kettle Utilization Rates (KUR), hop utilization is a measure of how much hop bitterness actually gets into your beer. Hop utilization varies from 0% for hops added at the end of boiling or used for dry hopping, up to a maximum of 25-33%.

There are several different formulas for determining hop utilization rates, devised by homebrew gurus such as Jackie Rager, Glenn Tinseth, Randy Mosher and others. All work equally well and give approximately similar values. When brewing, you should choose one formula and stick with it. One formula is given below:

IBU extraction formula: W x A x U x 7489 / V x C

Where: W = oz. hops, A% = Alpha Acid %, U = Utilization %, V = wort vol. in gallons, C = 1+ ((O.G. - 1.050) /2)) - a correction for wort gravity. 7489 is a conversion factor from mg/l to ounces per gallon.

Factors that aid hop utilization: Alpha acid extraction depends on a number of factors:

* *Lower wort concentrations.* Higher OG wort makes it harder for isomerized alpha acids to go into solution.

* *Longer boil times (up to a maximum of 2 hours).* Longer boil times give alpha acids more time to isomerize and get into solution. By contrast, flavor and aroma hops don't add as many alpha acids because they are exposed to heat for a shorter amount of time.

* *Sulfate additions.* Sulfate helps isomerize alpha acids.

Calculating Total IBU: To figure the total IBU extraction for a beer, you must calculate the IBU extraction for each hop addition, as described above, and sum the results.

Primary Methods of Extracting Hop Compounds

Bittering/Kettle Hops: These hop additions are responsible for most of the alpha acids in beer.

Kettle hops are boiled in wort for 60-120 minutes. Maximum bitterness utilization is 25-33%. Only humulones and cohumulones (IBU) are gained using this method; more volatile compounds are boiled away. The lovely hop aromas you get from the boiling wort represent flavor and aroma that *isn't* going into your beer!

For this reason, commercial brewers prefer high alpha acid varieties with relatively few essential oils as kettle hops. Higher alpha acids means fewer hops are needed, which helps to cut costs and also means that fewer polyphenols are extracted from the hops (although this is a relatively minor problem).

Maximum IBU extraction is obtained after about 120 minutes of boiling; there is no need for longer boil times.

Flavor Hops: Added 15-40 minutes before wort boil ends. IBU utilization is 5-15%, some volatile compounds are preserved, mostly the less volatile compounds which are only detectable in flavor.

Flavor hops walk the line between adding IBU and adding flavor and aroma additions to the beer. Brewers often use lower alpha acid hops, with higher levels of essential oils, as flavor hops.

Aroma Hops: Added 0-5 minutes before wort boil ends, or allowed to steep in hot wort after flameout. IBU utilization is 5% or less.

Aroma hops impart just the most volatile essential oils to the beer, typically those found in the aroma. As with flavor hops, brewers often use lower alpha acid hops, with higher levels of essential oils, as aroma hops.

Other Methods of Extracting Hop Compounds

Mash Hopping: Hops added to mash. Very little hop bitterness is extracted, but hop aroma and flavor compounds somehow survive the wort boiling process. Mash hopping is said to result in a smoother bitterness, but hop utilization is reduced by about 80%. Mash hopping is traditionally used when making Berlinerweisse.

First Wort Hopping: Hops are added to lauter tank during mash run-off and allowed to steep before being boiled. As with Mash Hopping, hop aroma and flavor compounds somehow survive the wort boil, but hop utilization is reduced. It is said to produce a more pleasant hop flavor, aroma and bitterness. This method is sometimes used when making German and Bohemian Pilsners.

Hopback Filtering: Hot wort is run from the kettle to the fermentation tank (or to the cooling tank or heat exchanger) through a filter or strainer filled with hops. This gives an effect very similar to aroma hopping, since the hops in the hopback only add hop aroma. A hopback also serves to partially filter the wort. Running wort through a hopback is a common English brewing technique.

Dry Hopping: Hops are added to the secondary fermenter or to the cask. Alcohol in the beer extracts the essential oils, which increases hop aroma. This is a common American and British brewing technique, which is less commonly encountered in German and Belgian brewing.

Practically, very few bacteria survive on hop and even fewer survive once the hops get in contact with the alcohol in the beer, so there is very little risk of infection from this technique.

Leaving the drop hops in a beer for a long period of time (months), or using massive amounts of hops might extract polyphenols (astringency, protein haze) or impart grassy notes.

Hop Fractions: Hop oils and alpha acids can be chemically extracted from hops and separated into individual compounds. A variety of hop oils are available, as are extracts of alpha acids. These are rarely available to homebrewers, but are sometimes used by large commercial brewers to standardize their products or to achieve a particular aroma or flavor profile. Hop fractions are also used to keep beer from becoming lightstruck, since the sulfur-bearing precursors to the lightstruck phenomenon are removed during the extraction process.

Important Hop Varieties

Hop Variety	Origin	Characteristics	Styles
Hallertauer Mittlefrüh, Tettnang, Spalt	German	"German Noble hops" with low bitterness, but complex, "elegant" spicy, floral notes. Used for flavor/aroma only. Often low IBU.	Munich Helles, Dortmunder Export, German Pils, Bock
Saaz	Czech	"Noble" hop with mild floral notes. Used for flavor/aroma only.	Bohemian Pils
Goldings, Kent Goldings, Fuggles	U.K.	Earthy, floral, spicy, woody notes. Medium IBU. Used for bitter, flavor & aroma.	Eng. Pale Ale, IPA & Barleywine
Cascade, Centennial, Columbus, Chinook, etc.	U.S. Pacific NW	Nicknamed "C" hops. Citrusy, grapefruity, piney. Medium to high IBU. Developed quite recently (early 1970s). Includes recent proprietary varieties (e.g., Amarillo, Citra, Warrior). So called "dual use" hops - can be used bitter & flavor/aroma.	American Pale Ale, IPA & Barleywine
Bittering Hops (e.g., Perle, Bullion, Galena, etc.)	All	High-alpha acid hops with lower levels of essential oils and/or "rougher" flavors & aromas. Mostly used for bittering.	All, esp. IPA, Barleywine

Other Hop Varieties

While these hop varieties aren't particularly important in themselves, they provide distinctive character to certain styles of beer described in the BJCP Guidelines:

Hop Variety	Origin	Characteristics	Styles
Cluster	U.S.	An old (19th century) American variety with a somewhat "rough" aroma and flavor. Mostly used for bittering.	Classic American Pilsner
Lublin	Poland	Polish-grow Saaz hops. Used for flavor & aroma.	Baltic Porter
Northern Brewer	Europe, America	Rustic, minty, woody. Used for bitter, flavor & aroma	California Common
Styrian Goldings	Belgian	Spicy. Used for bitter, flavor & aroma.	Witbier, Belgian Pale Ale
Strisselspalt	France	Similar to some German noble hops.	Saisons, Bière de Garde.

Noble Hops

The term "noble hop" is used to describe certain traditional varieties of German or Czech aroma/flavor hops.

* *Generally accepted noble varieties:* Hallertauer Mittelfrüh, Spalt(er), Saaz (AKA Zâtec) and Tettnang(er),

* *Terroir counts!* Noble varieties are only considered "noble" if they are grown in the area for which the hop variety is named. (i.e., noble Hallertauer can only come from the Hallertau valley in Germany). A U.S.-grown noble hop isn't noble!

- *Hallertauer Mittelfrüh:* Grown in the Hallertau (AKA Holledau) region in central Bavaria in Germany.
- *Spalt:* Grown in the the Spalter region south of Nuremberg, Germany.
- *Saaz:* Grown in Bohemia in the Czech Republic.
- *Tettnang:* Grown around the town of Tettnang in southern Baden-Württemberg in Germany.

* Chemically described as:

- 1:1 alpha : beta acid ratio.
- 2-5% alpha acid.
- low cohumulone & myrcene content.
- high humulene content.
- >3:1 humulene : caryophyllene ratio.

* *Prone to oxidation* = poor storage stability.

* Consistent bittering potential even when aged.

* *Debatably noble:* Certain hops have similar chemical profiles to the accepted noble varieties. For this reason, some brewers, scholars and beer writers argue that they should be considered "noble" as well. Debatably noble varieties include East Kent Goldings, Fuggles, Hersbrucker and Styrian Goldings, as well as modern descendents of the noble varieties grown in the traditional regions (e.g., Hallertauer Gold, Spalt Select).

Question T4 "Hops" Sample Answer.

Discuss:

1. Hop (Humulus Lupus) is a bine, native to N. latitudes of the N. hemisphere. First used in brewing in Germany in 1079, introduced to England in the 16th century. Replaced gruit (herb mixtures) as choice beer bittering agent. Alpha acids have mildly bacteriostatic action on gram-positive bacteria. Picked when slightly "papery," dried at ~100 °F, packed in airtight packages to prevent degradation of oils and resins. Terroir (where grown) has an effect on hop characteristics.

2. Active ingredient: Lupulins, fr. glands within the strobiles (cones) of female plant.

3. Soft Resins

A. Humulones = Alpha Acids: Alpha acids isomerized during wort boil, making them soluble in liquid. Contribute bitterness. AA = 3-10% of dry wgt. Co-humulones said to give a harsher bitter. AA lvl. drops as hops age, esp. if improperly stored.

B. Lupulones = Beta Acids. Don't isomerize, but contribute to bitter aroma.

4. Essential oils - volatile compounds give hop flavors/aromas. Easily lost during boil, retained by adding aroma, flavor and dry hop addit. Partially retained, through poorly understood means, via first wort hopping, mash hopping.

A. Hydrocarbon-based oils: ~75% of essential oils.

1. Monoterpenes: <u>Humulene</u> = delicate, refined flavor/aroma, oxidize to prod. spicy notes. High in noble hops. <u>Myrcene</u> = more pungent, higher in U.S. hops. Oxidize to prod. citrus or piney notes.

2. Sequiterpenes: Farnesene & Caryphyllene. Oxidize to compounds w. "grassy" aromas.

B. Oxygen-bearing oils: ~25% of essential oils. Essential alcohols. Linalool = hoppy aroma, Geraniol = floral, perfumy aroma.

IBU extraction formula: W * A * U * 7489 / V x C

Where: W = oz. hops, A% = Alpha Acid %, U = Utilization %, V = wort vol. in gallons, C = 1+ ((O.G. - 1.050) /2)) - a correction for wort gravity. 7489 is conversion factor from mg/l to oz./gal.

Hop Extraction Methods	Hop Characteristics
Kettle/Boil Hops - boiled 60-120 min. Max. bitterness utilization ~25-33%.	Bitter, Antibacterial/Preservative
Flavor hops - Boiled 15 - 40-min. Utilization = 5-15%.	Flavor
Aroma Hops - Boil 0 - 15 min., Steep after flame out. Utilization =< 5%.	Aroma
Mash Hopping - hops added to mash. Aroma & flavor preserved thru boil. Smoother bitter. Utilization red. by 80%	Bitter, Aroma, Flavor
1st Wort Hopping - added to lauter tank during mash run-off. Said to contribute more pleasant flavor.	Bitter, Flavor, Aroma
Hopback - Run hot wort through filter/strainer filled w. hops. Only adds aroma.	Aroma
Dry Hopping - Added to the secondary fermenter. Oils extracted by alcohol in beer.	Aroma

Hop Variety	Country	Characteristics	Assoc. Style
Hallertauer Mittelfrüh, Tettnang, Spalter	Germany	"Noble" hops w.Low bitter, high spicy, floral, complex aromas	Ger. Pils, Bock
Saaz	Czech Republic	"Noble" hop w. floral, mild flavor/aroma	Bohemian Pils
Kent Goldings, Fuggles	England	Good for bitter, flavor & aroma. Earthy, floral, spicy, woody	Eng. Pale Ale, Eng. IPA, Eng. Barleywine.
Cascade, Centennial, Columbus, Chinook	U.S. Pacific Northwest	Citrusy, grapefruity, piney. American "C" hops. Inc. recent proprietary var: Amarillo, Warrior, etc.	Am. Pale Ale, Am. IPA, Am. Barleywine
Northern Brewer	Europe, America	Rustic, minty, woody. Used for bitter,flavor & aroma	California Common
Styrian Goldings	Belgium	Spicy	Witbier, Belgian Pale Ale

Technical Question T8. "Water"

Discuss the importance of water characteristics in the brewing process and how water has played a role in the development of at least four distinct world beer styles. Address the following topics:

50%	**Describe the importance of water characteristics in the brewing process.**
50%	**Describe the role in the development of beer styles.**

Water constitutes 85-90% of beer by volume. It is unsuitable for brewing if: a) Detectable (i.e., testable) levels of metallic ions, b) High levels of pollutants, c) Smells and/or tastes bad for any other reason.

Most city water supplies are suitable for brewing, but must remove chloramines (more rarely chlorine). If not removed, these compounds can complex into unpleasant-tasting chlorophenols during the fermentation process. High levels of chlorine compounds are also toxic to yeast. Well water can have high levels of metallic ions, dissolved salts (e.g., Ca++, SO4-) or organic contaminants (e.g., Nitrates).

Boiling 30+ minutes will remove chlorine (but not chloramines). Adding potassium metabisulfite (Campden Tablet) and letting stand overnight will remove chloramines at a rate of 20 gallons per 50 mg sulfites (1 tablet). Charcoal filtration will remove both chlorine and chloramines, as well as metallic ions and some other contaminants (e.g., nitrates). Reverse Osmosis or distilled water will remove all contaminants and minerals. Ion exchange water softeners replace Ca++ ions with Na+ and are unacceptable for brewing.

Water drawn from rocks which are mostly composed of silicon, like sandstone or granite, is generally soft, as is rainwater or surface water runoff. Water drawn from other types of rock, such as shale or limestone, is harder and is higher in levels of dissolved ions.

Hard vs. Soft Water: Water with low levels of dissolved mineral salts (0-60 mg/l) is said to be "soft." Water with higher levels (60-120 mg/l) is moderately hard, water with high levels (121-180 mg/l) is "hard" and water with higher levels (181+ mg/l) is very hard. About 85% of homes in the U.S. (esp. in the Midwest, South and Southwest) have moderately hard or harder water.

Temporary vs. Permanent Hardness: Carbonate and bicarbonate compounds are responsible for temporary harness. Calcium, sulfate and chloride ions are responsible for permanent hardness. Temporary hardness refers to concentrations of mineral salts which can be precipitated out of solution by boiling or treatment with slaked lime. Permanent hardness refers to minerals which can't be removed (except by distillation or ion-exchange filters).

Total Hardness is the sum of both temporary and permanent hardness:

Total Hardness = Ca (ppm)/20 + Mg/12) x 50 = Total hardness CaCO3.

Total and Residual Alkalinity: Pure water has pH 7 (on a 0-14 log scale for pH), while alkaline water can have up to pH 8. (By contrast, beer has pH Total Alkalinity refers to water's ability to neutralize or buffer acids. It is roughly equivalent to carbonate alkalinity. , as measured by total plus permanent hardness. Alkalinity is mostly caused by Carbonates (CO3-) and Bicarbonates (HCO3-).

In brewing, alkalinity acts as a buffer to mash pH, preventing the mash from falling into the required pH 5.2-5.8 (5.4 optimal) range and must be countered by additions of acid (e.g., 88% lactic acid USP, less commonly 38% Muriatic/Hydrochloric acid - HCl) or dark malt (reduces mash alkalinity by 0.1-0.2 pH). Historically, a phytic acid rest at 95 °F for 2 hours was also used for some styles. Acidulated malt (AKA Sauermaltz) can achieve the same effects as acid additions.

Magnesium and calcium will reduce mash pH if added as salts which don't contain carbonate or bicarbonate (e.g., CaCl, CaSO4, MgSO4), but these. For this reason, salts such as calcium chloride, magnesium sulfate (AKA Epsom salts) or calcium sulfate (gypsum) are sometimes used to adjust mash pH.

Residual alkalinity (RA) refers to remaining alkalinity in the mash after malt phosphates complex with Ca++ and Mg+ ions in the mash.

Total Alkalinity = Ca (ppm)/3.5 + Mg (ppm)/7)

Residual Alkalinity = Temporary (Carbonate) Hardness - (Ca Hardness + 0.5 x Mg Hardness)/3.5.

6. Salt Additions: The problem is that excessive levels of ions can impart unwanted characteristics to beer.

D. Important Brewing Ions

Unless it has been distilled, water contains ions - positively or negatively charged atoms - from chemical compounds, usually salts, which have dissolved in the water.

For brewing purposes, these are the most important ions:

1. Metallic Ions: Iron (Fe+), Manganese (Mn+), Copper (Cu+), Zinc (Zn+). These are all necessary in trace amounts for yeast health. In excessive concentrations they can cause haze and produce metallic off-flavors. Metallic ions are generally present in sufficient levels in water that they don't need to be added.

2. Salts: These are simple water soluble chemical compounds consisting of a positively charged molecule or atom (a Cation) and a negatively charge molecule or atom (an Anion).

I. Cations: Positively charged ions:

A. Calcium (Ca++): The primary source of water hardness. Also described as temporary hardness. Reduces mash pH, 10-20 g/ml are needed for yeast nutrition. Calcium can be precipitated by boiling water and then letting it stand.

B. Magnesium (Mg++): The next biggest source of water hardness. Also described as *permanent hardness* because it can't be precipitated by boiling or lime treatments. It is an *important enzyme cofactor and yeast nutrient. At 10-30 mg/l it accentuates beer flavor.* At *higher levels* it imparts a harsh bitterness. At *125+ mg/l it is cathartic and diuretic.*

Sodium (Na+): Imparts a sour, salty taste to beer. At 2-100 mg/l it accentuates beer sweetness. Higher levels are harsh-tasting and are poisonous to yeast.

II. Anions: Negatively charged ions.

A. Carbonate/Bicarbonate (HCO_3-, HCO_3- -): Sometimes expressed as alkalinity or temporary hardness. These compounds are strong alkaline buffer which raise mash pH and neutralize acids. They can contribute a harsh, bitter flavor to beer. Their alkaline effects are traditionally countered by brewing beers made with dark malts. Carbonates also help extract color from malt, giving darker colored beers.

B. Chloride (Cl-): At 200-400 mg/l chloride accentuates sweetness, "mellowness" and perception of palate fullness. It also improves beer stability and improves clarity. Excessive levels can be bitter and salty.

C. Sulfate (SO_4- -): Also described as *permanent hardness* because it can't be precipitated by boiling or lime treatments. Sulfate ions *impart dryness, fuller flavor and astringency* to beer. They also *aid alpha acid extraction* from hops and *increase the perception of hop bitterness.* These effects become more concentrated *at 200-400 mg/l. At levels above 500 mg/l sulfate becomes highly bitter.*

E. Famous Brewing Waters

Burton-on-Trent: High total alkalinity and moderately high permanent hardness, with very high levels of calcium carbonate and calcium sulfate. This gave Burton beers a drier, fuller finish and accentuated hop bitterness.

[In the early 19th century, the superiority of Burton water led to them taking much of the pale ale trade away from the London brewers. By about 1850, however, London brewers had learned to "Burtonize" their water, by adding mineral salts.] *Beer Styles:* English Pale Ale, IPA [Strong Ales].

Dortmund: High total alkalinity and permanent hardness, with high sulfate and moderate carbonate levels. This accentuates hop bitterness and imparts "mineral" & sulfury hints. [Historically, Dortmunder export was developed in the 1890s, after brewers had a keen understanding of water treatment, so local water character probably didn't play a big role in the emergence of the Dortmunder style. According to Jamil Zainasheff, Dortmunder brewers probably treated their water.] Beer Style: Dortmunder Export.

Dublin: High total alkalinity, moderately high permanent hardness. Moderate levels of sulfates, very high levels of carbonates. Somewhat similar to London, so highly suited to brewing dark and amber beers. Beer Styles: Dry Stout [Porter, Irish Ale].

Edinburgh: Medium carbonate water with medium calcium levels and low sulfate levels. Before Edinburgh brewers sunk wells in the 18th century, they might have used surface water which ran off from local peat bogs, which would have added "smoky" notes to their beer.

[By the late 18th century Edinburgh brewers had access to both hard and soft water, sometimes within the same brewery, and could brew any style of beer they wanted. They were also major exporters of IPA and pale ales. The idea of commercial brewers using peaty surface water is nonsense since brewers of the period tried to avoid smoke flavors and surface water was likely to be badly polluted. But, "print the legend."] *Beer Styles:* Scottish Ales, Scotch Ale. [And, actually, any style of ale. But, "print the legend."]

London: Medium to high total alkalinity and medium to high permanent hardness, with medium levels of sulfate and calcium. Well suited to producing dark, sweet beers. [Actually, there is no one profile for London water - it varies widely depending on the depth of the well, the location of the brewery, and in some cases, the flow of the tide up the Thames. Water drawn from the river itself is even more variable! Also, by about 1850, London brewers learned to treat their water by adding mineral salts. That said, the profile given above is fairly typical.] *Beer Style:* Brown Porter, [Sweet Stout, Southern English Brown, Pale ales].

Munich: *High total alkalinity and moderately high permanent hardness.* It also has *high levels of sulfates.* [Historically, Munich brewers learned to adjust their water chemistry about the same time that everyone else did. Since most Munich beer styles emerged in their modern form after 1850, water character probably didn't have much to do with the development of modern Munich beers. It's also odd that despite the high sulfate water, most Munich styles are malty!] *Beer Style:* Munich Dunkel [Dark and amber lagers, Bocks].

Plzen: Extremely soft water, with very low total alkalinity, and low overall ion levels. As close to pure water as ground water gets. Lack of ions decreases perception of hop bitterness, and historically made acid rests and decoction mashing necessary due to lack of minerals to aid enzymatic reactions in the mash. Beer Style: Bohemian Pilsner.

Vienna: High total alkalinity and moderately high permanent hardness. High in calcium and medium high in carbonates. Somewhat similar to London or Dublin. Suited to amber or dark, sweet beers. Beer Style: Vienna Lager [Amber Lager].

Question T8 "Water" Sample Answer

Treatment	Effects
Boiling	Removes chlorine, kills bacteria
Charcoal Filtration	Removes chlorine, chloramines & metallic ions.
Campden Tablets	1 tablet/20 gal. H20, converts chloramines to volatile chlorides & sulfites w/in 15 minutes.
Reverse Osmosis	Removes most bacteria, chlorine, chloramines and ions. 100% r/o water not recommended – insufficient minerals for yeast development/mash enzyme action.

Important Ions	Level (ppm)	Effect
Iron (Fe), Manganese (Mg), Copper (Cu), Zinc (Zn)	trace	Necc. in trace amounts for yeast health. Excessive (i.e., detectable) lvls. = haze, metallic off-flavors.
Salts - Cations		
Calcium (Ca++)	50-150	Primary source of permanent hardness. Reduces mash pH, Aids beer clarity, flavor and stability. 10-20 ppm needed for yeast nutrition, 50 ppm needed for proper mash enyzme, boil reactions.
Magnesium (Mg++)	10-30	Second. source of perm hardness. Enzyme cofactor & yeast nutrient. Accentuates flavor @ 10 -30 ppm. >50 = harsh bitterness. >125 ppm = laxative & diuretic.
Sodium (Na+)	0-150	Gives salty and sour taste. 70-100 ppm accentuates sweetness 200+ = salty, harsh bitter w/ SO4, poisonous to yeast.
Salt - Anions		
Bicarbonate/Carbonate (CO3, HCO_3-)	0-250	Main source of Temp. Hardness and Total Alkalinity. Strong alkaline buffer - raises mash pH, neutralizes acids. Contributes harsh, bitter flavor. Alkaline effects trad. countered by using dark malt. 0-50 ppm for pale beers, 50-150 for amber/brown, 150-250 for dark, roasted beers.
Chloride (Cl-)	0-250	Accentuates sweetness, "mellowness" & perception of palate fullness. Improves stability & clarity. >300 ppm = chlorophenols.
Sulfate (SO_4-)	0-350	Part of perm. hardness. Accentuates hop bitter. Prod. dry, fuller flavor. 0-50 ppm for malt-focused, 50-150 for normal, 150-350 for very bitter beers. Some sharpness. >400= v. harsh bitter > 750 ppm = laxative.

pH (Power of Hydrogen): Pure water/neutral = pH 7. Acidic = 0-6 (e.g., Beer ~3.2-3.8), Alkaline = 8-14.

Proper mash pH = 5.2 - 5.8 pH. > 5.8 pH = Polyphenol/tannin & silicate extraction. < 5.2. pH = Enzyme probs. Mash pH drops naturally due to reax. of phosphates in malt & Ca++ and Mg+ions.

Total Alkalinity = Temporary - Perm. Hardness.

Residual Alkalinity = Remaining alkalinity in mash after malt (phosphate & Ca++ or Mg++ reax.) and acid additions. High carbonate H2O or adding carbonates increases RA, adding acids (e.g., 88% USP Lactic), Ca++, Mg++ (as CaCl, MgSO4 or MgCl) reduces it.

Acids used to adjust pH: Lactic acid, sulfuric acid (used by commercial breweries for cost reasons). Phosphoric can mess with calcium levels, so not recommended. Acidulated malt (sauermaltz) = sour-mashed and dried malt, or sour mash (base malt inoculated with Lactobacillus Delbruckii & held at 120 °F for 1-3 days) used for Reinheitsgebot-compliant breweries. Must be careful w. pH adjustments to avoid imparting sourness & getting mash pH too low. More necc. w. alkaline H2O or mash using just pale malts.
Acid Rest: ~95 °F for up to 2 h. Tradit. Used for Bohem. Pils. Convert phytins in malt to phytic acid in undermodified light malts. Not necc. w. modern malts.

Famous Brewing Waters

City	Beer Style	Water Effects
Burton-on-Trent	Eng. IPA	Extremely hard, high CaSO4e & HCO3- lvl. Dives dry, fuller finish & accentuates hop bitter.
Dortmund	Dort. Export	High SO4-, med. HCO3. Accentuates hop bitter. Gives "mineral" & sulfur hints.
Dublin	Dry Stout	High Ca++ & HCO3. Balances acidifying effect of dark malts.
Edinburgh	Scottish Ale	Med. HCO3. Surface water running through peat bogs "historically" added "smoky" notes, accentuated by yeast strain & lower ferment. temp.
London	Brown Porter	High alkaline & carbonate water balances acidifying effect of dark malts, extracts color.
Munich	Munich Dunkel	High alkaline & carbonate water balances acidifying effect of dark malts, extracts color.
Plzen	Boh. Pilsner	Extrem. soft H20, w/ v. low dissolved ions. Decrease. hop bitter. Acid rest & decoction mash trad. necc. due to lack of minerals to aid enzymatic reax. in mash.
Vienna	Vienna Lager	Hard, carbonate-rich water extracts the color from Vienna malt.

Technical Question T9. "Kräusening, Gypsum & Finings"

Discuss the brewing techniques a) kräusening, b) adding gypsum, and c) fining. How do they affect the beer? Address the following topics:

50%	**Describe each characteristic.**
50%	**Identify the effect on the finished beer.**

1) Adding Gypsum

Describe: Gypsum (calcium sulfate, $CaSO_4$) is a common brewing British salt, found naturally in high levels in the water of Burton-on-Trent. It is an important part of "Burton salts" used to impart increased hop bitterness to English pale ales and IPA. When added to brewing water, it increases the level of calcium (Ca++) and sulfate (sulfate (SO_4- -) ions.

Effect on Beer: When added in proper amounts, gypsum *aids the mash by adding necessary calcium* (at least 50 ppm of calcium are necessary for proper mash enzyme function) and *adjusting mash pH* into the optimum range. Calcium also *aids yeast nutrition*, resulting in shorter lag times once yeast is pitched and faster, healthier fermentation.

Sulfate ions impart dryness and fuller, more lingering bitterness to beer but can be astringent in excess. Sulfates also *aid alpha acid extraction* from hops and increase the perception of hop bitterness. These effects become more concentrated at 150-350 mg/l. Above 400 mg/l sulfate becomes highly bitter.

Excessive levels of gypsum *can give beer a harsh minerally taste and unpleasant hop bitterness*; this is a common homebrewing mistake, especially for brewers using old English recipes which call for adding a teaspoon of gypsum.

Gypsum is best used when adjusting low or moderate hardness, low sulfate water to mimic Burton water when brewing English-style bitters, IPA and strong ales. It isn't necessary when brewing with water which naturally has high levels of carbonates and sulfates.

When attempting to adjust water to mimic Dortmund water, it is generally better to add Epsom salts (magnesium sulfate) instead - as long as magnesium levels don't go above 30 mg/l. In any case, gypsum should be added carefully to avoid excessive amounts.

2) Finings - Repeated from Cloudiness in Troubleshooting

Describe: Finings are a solution of fine particles which are added to wort or green beer in order to *increase the rate at which suspended material flocculates* and falls out of solution. Fining particles are positively or negatively *electrostatically charged*, so that they attract other particles to them. The larger clumps of material precipitate faster. *At least 50 mg/l calcium is necessary* in the wort or beer in order for most finings to work. All types of finings clarify beer and aid flavor stability.

Effects on Beer: There are two classes of finings, which can be added at different stages of the brewing process:

1) Kettle/Copper Finings: Help coagulate hot break, - proteins responsible for protein/chill haze and flavor instability. All work by coagulating proteins. Typical kettle finings are: *Irish moss* (dried seaweed - Chondrus *Crispus* - at 50 - 150 mg/l), *Protofloc*^{TM} (30 mg/l), *carrageen* (a gum used in food production - derived from seaweed), and *Whirlfloc*^{TM} (20-60 mg/l). All are added at the rate of approximately 1 tsp or tablet/5 gallons in the last 15 minutes of the wort boil.

2) Fermenter/Cold Side Finings: *Either added to conditioning vessel* near the end of conditioning period *or added to the cask* (for cask-conditioned ales). *Used to remove yeast, protein, polyphenol or starch hazes.* Fining are often packaged as powders and must be rehydrated using sterilized hot water. They take time to work - at least 25 hours.

Common yeast flocculants are *isinglass* (dried collagen obtained from the dried swim bladders of fish, historically sturgeon or cod, now various fish species from the South China Sea. Added at 1-3.5 mg/l at 42-55 ºF), *brewers' gelatin (added at 60-90 mg/l - not as effective as isinglass).* These finings work best if the beer is cold (below 50 °F).

Polyclar^{TM} or PVPP (tiny beads of polyvinyl pyrrolidone - plastic) is a polyphenol binder used to remove chill haze (6-10 g/5 gal).

S*ilica gel* is a protein binder used to remove protein haze (usually added at 1-3.5 mg/l).

3) Kräusening

Describe: Kräusening is a technique where *a portion of actively fermenting wort* (from another batch of beer at the high kräusen phase of the Fermentation stage of the yeast's life cycle) *is added to green beer* which has finished fermenting (where the yeast is at the Sedimentation stage of the yeast life cycle), just prior to packaging. This *provides active, healthy yeast to supplement dormant/dying yeast lost during extended lagering.* It is most commonly used when making German lagers or wheat and rye beers.

This technique is often used by commercial brewers who brew the same varieties of beer on a regular schedule. Even for those brewers who don't bother with the Reinheitsgebot, the practical benefit is that you can top up the headspace in your conditioning tanks with kräusen once fermentation subsides, increasing the volume of beer in your tanks and possibly freeing up tank space.

Typically, 10-20% of fresh wort is added depending on desired level of carbonation and batch size. For a 5 gallon batch of homebrew, this works out to 2-4 quarts. When homebrewers use this technique, they generally make a second yeast starter, sometimes using canned wort from the batch of beer to be kräusened, and add that to the raw beer.

The practice of adding unfermented wort (speise) to carbonate finished beer is related to kräusening, but technically isn't the same thing.

Effects on Beer: For brewers who wish to comply with the Reinheitsgebot, kräusening *provides natural carbonation* for beer without adding sugar or artificial carbon dioxide. Actively fermenting yeast *helps scavenge VDK (diacetyl) & acetylaldehyde* still present in the packaged beer, and *also helps fully attenuate high gravity lagers.* Conversely, yeast in the *kräusen can also impart these off flavors* if they can't complete their fermentation in the bottle. *Kräusening can also result in infection* of the bottled beer, or the beer from which the kräusen came, if the brewer doesn't practice proper sanitation procedures. Finally, if the wort used to kräusen isn't identical to the beer to be kräusened, *the brewer must recalculate vital statistics* like ABV, IBU and SRM.

Technical Question T10. "Hot & Cold Break"

What is meant by the terms hot break and cold break? What is happening and why are they important in brewing and the quality of the finished beer? Address the following topics:

30%	**Describe each term.**
30%	**Identify what is happening.**
40%	**Describe why they are important in brewing and the quality of the finished beer.**

1) Hot Break

Describe: Hot break (AKA Kettle Break) is an albuminous precipitate formed primarily during the first 5-20 minutes of the wort boil (Palmer, p. 81), consisting of denatured high molecular-weight proteins which have polymerized with carbohydrates and polyphenols (especially tannins, but also anthrocyanogens and flavanols) but also containing contains lipids and other compounds. The exact composition is about 50-60% protein, 20-30% polyphenols, 15-20% hop resins, and 2-3% "ash" (i.e., other materials, such as insoluble salts).

It forms at a rate of about 20-40 ppm. When it first forms it appears as a brownish or greenish scum on the top of the boil kettle and is a major factor in boilovers. In suspension, the trub particles initially have the appearance of small whitish flakes which grow larger as flocculation continues. By the end of the boil, the break can have the appearance of egg whites in egg-drop soup. When precipitated, it mixes with hop debris and has a greenish-brown slimy appearance.

What's Happening: Hot break begins forming at the start of the wort boil (at 212 °F). 60% of the hot break is formed within the first 5% minutes of boiling, but longer boils times will increase this figure, up to 95% protein removal after a 2 hour boil. (Barchet) The proteins coagulate, clump together and sink to the bottom of the brew kettle. They can then be separated from the rest of the wort when it is transferred to the fermentor.

The chemical process which causes the hot break is electrostatic attraction - the same principle which allows various types of finings to work. At wort boiling temperatures, normally soluble proteins are denatured by the heat, increasing their positive charges, making them more electrostatically attractive. They then interact with negatively charged polyphenols (mostly tannins), carbohydrates, lipids and other materials to form larger molecules which precipitate more quickly and which can be more easily filtered.

Hot break should be removed from the wort before it is chilled. Methods of removing the hot break include settling, filtration, hopbacks and whirlpooling. (Barchet) It can also be skimmed off the top when it foams up as the kettle comes to a boil.

Factors Affecting Hot Break Formation

1) Type and amount of malt and adjuncts. Grains higher in proteins and beta-glucans produce more hot break. This includes malts made from poor-quality (i.e. high nitrogen) or poorly modified malt (e.g., traditional American 6-row, although modern malts are all relatively low in nitrogen). This also includes other types of grains or malts with high proteins or beta-glucan levels, such as wheat, rye and oats.

2) Mashing schedule: An excessively short or long protein and/or beta-glucan rest will reduce hot break formation. An insufficiently long rest leaves most of the proteins and beta-glucans in the grain, while an excessively long rest will break down long-chain proteins into polypeptides and peptides, which are more soluble in wort.

3) Boil Time: *A full, rolling boil of 60+ minutes* is necessary for sufficient *proteins to precipitate*, but hot break is *maximized by a 2 hour, extremely agitated boil*. With well-modified modern malts, however, there is less need for long or aggressive boils (as little as a 2% volume reduction using modern malts). At wort boiling temperatures, normally soluble proteins are denatured by the heat, increasing their positive charges, making them more electrostatically attractive.

4) Boil Vigor: Rolling boils are necessary to agitate the wort, so that the molecules which form the hot break can better interact. *Hot break is improved by a quick rise to boiling temperature.*

5) Wort pH: Low pH worts (below 5.3 at room temperature) render proteins more soluable, making them harder to precipitate. Worts below pH .50 make hot break impossible.

6) Presence of polyphenols: The presence of tannins, and to a lesser extent, anthrocyanogens and flavanols, increases hot break formation. In properly produced wort, most of these products will come from boiling hop additions, but in wort where particles of grain husks have been carried into the wort, or where tannins have been extracted from grain husks by improper mashing techniques, there may be significant levels of malt-derived tannins as well. If not precipitated, these will be a major contributor to chill haze.

7) Kettle finings: Kettle finings, such as Irish Moss or Whirlfloc™, aid in the precipitation of the hot break. Bentonite added to the boil achieves the same effect. The positively charged fining particles attract negatively-charged tannins and carbohydrates helping them to flocculate and increasing the rate at which they precipitate.They are typically added 15-20 minutes before knock-out so they have time to work.

Why is it Important?: A good hot break is necessary for storage stability and to reduce haze formation. If not precipitated, tannins and proteins can complex at cool temperatures to form an unsightly haze, while suspended medium- to long-chain polypeptide and starch molecules can form hazes at any temperature.

Just as important, if not precipitated and removed from the wort before it is pitched, fatty acids (lipids) present in the beer can oxidize during conditioning or storage to produce a variety of unpleasant oxidized notes, primarily papery, cardboard-like aromas and flavors (trans-2-nonenol), but also goaty, sweaty or rancid notes (caproic, caprylic and capric acids). Polyphenols carried into the wort can oxidize to produce harsh, astringent "solventy stale" (furfural ethyl ether) notes and haze. Oxidation of proteins can result in permanent haze.

If *hot break* isn't removed from the wort before it goes into the fermenter, it will be *carried over into the finished beer,* where proteins in the hot break *can cause off-flavors, chill/protein haze and flavor instability*. High levels of hot break products in the fermenter can also cause the yeasts to produce *excessive levels of fusel alcohols & sulfur compounds*.

2) Cold Break

Describe: Cold break is the *coagulation and precipitation of proteins, carbohydrates and other materials during wort cooling*. It consists of short- and medium-chain proteins polymerized with carbohydrates and polyphenols not precipitated during the hot break, as well as up to 50% fatty acids (mostly oleic and linoleic acids). It has the appearance of egg whites in egg-drop soup.

What's Happening: Cold break begins at about 140 °F and is maximized if the wort is rapidly cooled to a temperature of less than 70 °F.

Short- and medium-chain protein and carbohydrate molecules, which were previously soluable in the wort at boiling temperatures, become insoluble as the wort cools and its saturation point decreases. As the molecules fall out of solution, they are electrostatically attracted to each other, flocculate and precipitate just like the hot break.

Material congealed by the rapidly cooling temperatures sinks to the bottom of the kettle, so that it remains behind when the wort is transferred to the fermentor. Commercial breweries sometimes *increase removal of cold break by whirlpooling* the cooled wort or by running it through a *hopback or filter*. *Some cold break should remain* in the wort to provide yeast nutrition, however.

Factors Affecting Cold Break Formation

1) Type and amount of wort and adjuncts: As for Hot Break.

2) Wort pH: As for Hot Break.

3) Presence of polyphenols: As for Hot Break.

4) Use of Finings: As for Hot Break.

5) Rapid Cooling: Quick cooling results in better cold-break formation (Miller, p. 134, Noonan, p. 249). Ideally, the wort will be chilled to as low a temperature as possible (down to 32 °F)

Why is it Important?: If *cold break* isn't removed from the wort before it goes into the fermenter, it will be *carried over into the finished beer*, where proteins and polyphenols (tannins) in the cold break *can cause off-flavors, chill/protein haze and flavor instability*. High levels of cold break products in the fermenter can also cause the yeasts to produce *excessive levels of fusel alcohols & sulfur compounds (DMS)*. Reduced cold break also increases the clarity of the finished beer.

A good cold break is necessary to remove lipids from wort, as well as additional proteins, tannins and carbohydrates not precipitated by the hot break. Removal of lipids results in better head formation and stability, and prevents staling (Fix, p. 29). Some of the fatty acids present in cold break are necessary for yeast development and health (they are used for form yeast cell walls), so some cold break should be carried into the fermenter. Trub particles can also act as nucleation sites for CO2 bubbles to form, helping to remove CO2 from the fermenting wort, further aiding yeast metabolism.

Some commercial breweries pitch their yeast into partially clarified wort, let the yeast work for 12-24 hours and then transfer the fermenting wort into the main fermentation tank, leaving most of the break behind.

The Cold Break also helps to precipitate complexed proteins and polyphenols responsible for chill haze, as described for hot break.

If hot and/or cold break are carried into the fermenter, the higher levels of amino acids and fatty acids will result in the yeast producing higher levels of higher alchols and lower levels of esters.

Technical Question T11. "Diastatic and Proteolytic Enzymes"

Describe and explain the role of diastatic and proteolytic enzymes in the brewing process and how they affect the characteristics of the finished beer. Address the following topics:

50%	**Describe and explain the role of diastatic and proteolytic enzymes in the brewing process.**
50%	**Describe how they affect the finished beer.**

1) Proteolytic Enzymes

Works on: Proteins.

Optimum Temperature: 113-122 °F (active 103-122 °F).

Describe/Explain: * Naturally occur in malt. * In the mash, they degrade larger proteins in the malt into smaller proteins and amino acids. * Typical protein rest ~120 °F for 15-20 minutes. * Proteinase breaks down proteins into smaller fractions such as polypeptides, which are necessary for good head retention. * Peptidase breaks down polypeptides into peptides & amino acids, essential for proper yeast growth &

development.* Highest enzyme levels in pale, fully-modified malts. * No enzyme activity in crystal/caramel or roasted malts.

Effects on Beer: * Reduces cloudiness. * Aids lauterability of mash when using high-protein malts (e.g., wheat, rye). * Aids head retention. * Aids yeast health. * Too long a protein rest (1+ hour) can reduce head & body. * Insufficient peptides and amino acid levels can lead to poor yeast health, indirectly causing yeast-derived off-flavors (e.g., diacetyl, acetaldehyde, higher alcohols) and reduced wort attenuation.

2) Diastatic Enzymes

Works on: Starches.

Describe/Explain: * Begin working when starches are gelatinized by being soaked and heated in the mash (temperature varies, usually 80-160 °F). * In the mash, they degrade larger starches in the malt into smaller starches (dextrins) and fermentable simple sugars (e.g., mono & disaccharides). * Naturally occur in the malt. * Highest enzyme levels in pale, fully-modified malts. * No enzyme activity in crystal/caramel or roasted malts. * The two most important diastatic enzymes are Beta Amylase and Alpha Amylase.

A) Beta Amylase (Optimum temperature range: 130-150 °F. Denatured above 154 °F): * Produces monosaccharides (e.g., maltose, glucose). * Breaks off maltose units from reducing ends of starches by cleaving 1-6 bonds. * Unable to quickly reduce large starch chains. * Unable to reduce branched starch chains.

Effects on Beer: Creates more fermentable wort, thinner bodied beer with lower head fullness and retention.

B) Alpha Amylase (Optimum temperature range: 149-158 °F. Denatured above 167 °F): * Breaks links from starches at random by cleaving 1-4 bonds. * Produces short-chain starches and polysaccharides (e.g., dextrins). * Unable to completely reduce branched starch chains. * Aids action of beta-amylase by creating more reducing ends for them to work on.

Effects on Beer: Creates more dextrinous wort, thicker bodied beer with higher head fullness and retention.

Remember

M.A.L.T. = More Alcohol, Lower Temperature.

Beta Amylase: It’s “beta” because it’s a “wimp” compared to alpha amylase. It can’t stand higher temperatures and it nibbles on molecule ends while alpha randomly tears apart big starch molecules. It’s also the “first act;” alpha amylase comes in afterwards to finish the action.

Technical Question T13. “Mashing”

Explain what happens during the mashing process, including times and temperatures as appropriate. Describe three different mashing techniques and the advantages and disadvantages of each. Address the following topics:

50%	**Explain what happens in the mashing process, including times and temperatures as appropriate.**
30%	**Identify and describe three mashing techniques.**
20%	**Identify and describe three different mashing techniques and the advantages and disadvantages of each.**

1) Mashing Basics

* Mashing is the process of heat and soaking malt to hydrolyzing enzymes and gelatinizing starches within.

** Enzyme action breaks down proteins and starches* within the mash for optimum yeast health and nutrition.

* “Rests” at certain temperatures, for certain lengths of time, favor the action of various enzymes.

- Rest temperature ranges can overlap.

* Mashing creates fermentable sugars in the wort.

* Mashing gives you full control over wort composition.

* M.A.L.T. = More Alcohol, Lower Temperature.

2) Milling

Milling is a pre-cursor to mashing.

* It crushes the contents of the kernels, increasing the amount of surface area available for hydolyzation and enzyme action.

* Grain husks form a filter bed which helps clarify mash run-off during lautering and sparging.

* If grains are milled too coarsely (a coarse “crush”) the following problems can occur:

- increased dough-in time.
- reduced enzyme efficiency.
- reduced extract yield.

* If grains are milled too finely (a “fine crush”) the following problems can occur:

- increased risk of stuck mash.
- trouble with wort clarity.
- bits of husk carried into wort during sparging (resulting in polyphenol extraction during wort boil, which causes protein haze and astringency).

3) Mash Requirements

A) **pH range: 5.2-5.8.** You usually need to adjust water chemistry to get you water into this range: additions of mineral salts, acids, or use of dark or acidulated malt.

- Test using pH strips or pH meter.
- Higher pH causes trouble with tannin extraction, reduced enzyme efficiency.
- Lower pH causes reduced enzyme efficiency.
- Modern buffering solutions (e.g., Five Star 5^2™) get pH into optimum range without need for acid additions or salt additions.

B) At least 50 mg/l Ca++ for optimum mash efficiency.

C) Starch Conversion Test: To get optimum extract yields and to check for full conversion.

- *Iodine test:* Take a drop of liquid from the mash and put it on a white porcelain plate. Add a drop of iodine (Iodophor™ will work) to it. If the sample turns dark purple, starch conversion is incomplete.
- Most homebrewers don’t bother. With well-modified malts, a mash of 30-90 minutes guarantees full conversion.
- Incomplete starch conversion can result in starch haze.

4) Mashing Steps

Using a step mash regime, all these steps are possible, although they aren’t always necessary. With an infusion mash, only dough-in and saccharification are possible.

A) ***Dough-In (10-15 °F higher than 1st rest temperature):*** *Grist is mixed with water, hydrolyzing enzymes and allowing them to work.* * Water temperature drops to desired rest temperature as it is cooled by room-temperature grist. * ~1.3 quarts water/lb. grist. * Break clumps so no dry grist remains. * Mix thoroughly to get temperature even.

B) ***Acid Rest (95-120 °F, for 60-120 minutes):*** * Phytase breaks down phytin in grain husks, producing phytic acid, Mg++ & Ca++. * Reduces mash pH in pale, undermodified grains & low Ca++ water. * Creates yeast nutrients. * *Not necessary with modern malts and proper water treatment.*

C) ***Beta Glucanase/Starch Rest (~110 °F for 15-30 minutes):*** * *Betaglucanase reduces hemicellulose & gums* (Beta glucans) in cell walls which can contribute starch haze & cause stuck mash.* Only needed for under-modified or high-protein (e.g., wheat, oats) malt only. * *Usually run concurrently with Protein Rest and/or Ferulic Acid Rest.*

D) Ferulic Acid Rest (~110 °F for 15 minutes, at pH < 5.7): * Liberates ferulic acid, precursor to 4-vinyl guaiacol, in wheat malt. * Slightly aids in production of clove flavor for German wheat beers (although yeast strain and fermentation temperature is more important). * Only need to mention this if you're a smartass trying for a master score!

E) Protein Rest (113-127 °F for 15-60 minutes): Protease enzymes (proteinase & peptidase) degrade large (albuminate) proteins into smaller fractions such as polypeptides, and degrade polypeptides into peptides & amino acids, essential for proper yeast growth & development. * Important when mashing undermodified or high-protein (e.g., wheat) malts. * Generally not necessary with fully-modified malts. * Excessively long protein rest (1+ hour) can result in thinner body and reduced head formation and retention. * Skipping protein rest can result in stuck mash or excess body, haze and storage instability in finished beer.

F) Saccharification/Starch Conversion Rest: * Diastatic enzymes (alpha and beta amylase) degrade starches into dextrins and fermentable sugars. * Different enzymes work optimally at different temperatures. * Altering temperature favors one over the other. * Mash at 150 °F to get a balance between the two types of enzymes. * Enzymes produce monosaccharides (glucose, fructose, mannose, galactose), disaccharides (maltose, isomaltose, fructose, melibiose, lactose), trisaccharides (maltriose) and oligosaccharides (AKA dextrins = glucose chains).

I. ***Beta Amylase Rest (130-150 °F for 15-90 minutes. Denatured at 164 °F):*** Favors the action of Beta Amylase which cleaves 1-6 bonds at the reducing ends of starch chains to produce monosaccharides. * *Yields wort very low in dextrins, high in fermentables * Produces thinner-bodied, drier, more alcoholic,* more "digestible" beer, with *poorer head formation and retention.*

II Alpha Amylase Rest (149-158 °F for 15-90 minutes, denatured at 168 °F): Favors the action of Alpha Amylase which randomly cleaves 1-4 bonds of starch chains to produce oligosaccharides. * Yields wort higher in dextrins, and lower in fermentables * Produces fuller-bodied, sweeter, less alcoholic, starchier beer with better head formation and retention.

G) Mash-Out (168 °F for 5-15 minutes): * Denatures enzymes, stops starch conversion. * Reduces viscosity, aids mash run-off. * Mash temperature should not exceed 168 °F to avoid tannin extraction.

5) Mashing Techniques

The four major types of mashing are listed below. Remember you only need to know three for the exam!

A) Infusion Mash

Describe: Grist is mixed with hot water at starch conversion temperatures and is allowed to rest at that temperature for the entire duration of the mash.

Advantages: Requires a minimum of labor, time, energy, equipment & skill. Suitable for use of well-modified malts.

Disadvantages: * *Little control over mash temperature* after dough-in (except to add more water). * Prevents use of undermodified malt. * Limits use of adjunct grains (if they require a cereal mash or protein rest).

B) Step Mash (AKA Temperature-Controlled Mash, Step Infusion Mash)

Describe: The mash is held at various temperatures for specific periods of time, starting with the lowest temperature rest on the schedule. *When the first rest is completed, the mash is then directly or indirectly heated to raise it to the next rest temperature.*

Advantages: * *Increased control over wort composition.* * Allows use of undermodified malts. * Allows use of high-protein/gummy adjunct grains and malts. * Allows mash-out without adding water.

Disadvantages: * *Requires extra time, equipment, labor and skill.* * Directly heating the mash tun can potentially scorch mash. * Adding hot water to mash tun to raise temperatures can result in excessively thin mash, raise pH out of proper range or result in wort with insufficiently high specific gravity.

C) Decoction Mash

Describe: A simple, traditional German form of temperature-controlled mash where part of the mash is removed from the main mash tun, heated to boiling in a separate container, held there for a certain amount of time and then returned to the mash to raise overall mash temperature.

Steps are as follows: 1. Dough in at first desired rest temperature. 2. Remove a third of thick portion of the mash. 3. In another kettle, briefly raise the decoction temperature saccharification temperatures (2-5 minutes). 4. Boil the decoction for 15-30 minutes, stirring constantly and adding water as necessary to avoid scorching. 5. Mix the decoction back into the main mash to raise overall temperature. Mix thoroughly to avoid hot spots in the mash. 6. Repeat up to 2 times.

The formula for raising the mash temperature using a decoction is:

Decoction volume = total mash volume x (target temp - start temp) / (boil temp - start temp)

* *Triple decoction mashes* were traditionally used for Bohemian Pilsner, Traditional Bock, Doppelbock and Munich Dunkel.

* *Double decoction mashes* were traditionally (in the 19th and 20th centuries) used for other styles of German beers. Until recently, variations on the double decoction mash were used for most styles of German beer.

* A single decoction mash is mostly commonly used to get to mash-out when otherwise using an infusion mash. It is well-suited to modern, well-modified continental lager and amber malts.

Advantages: * *As for Step Mashing.* Additionally: * Explodes starch granules. * Breaks down protein matrix in undermodified malt. * Improves extraction efficiency when using undermodified malt. * Promotes formation of melanoidins. * Can caramelize sugars (but at risk of scorching). * Allows brewing without thermometer (since adding a decoction back into the mash naturally elevates it to the next rest on the schedule of acid rest, protein rest, saccharification rest and mash-out).

Disadvantages: ** As for Step Mashing. * Extremely labor and time intensive.* * Requires extra equipment and space. * Extra energy required. * Direct fired decoction vessel required. * Risk of scorching decoction. * May extract higher levels of tannins & DMS precursors from grain husks.

D) Cereal Mash (AKA Double Mash)

Describe: This technique actually consists of *two separate mashes which are blended to reach saccharification temperatures.* The main mash consists of crushed malt, while the second (cereal) mash consists of raw adjunct grains and just a bit of crushed malt. The *cereal mash boiled for 1 or more hours to gelatinize starches, then added to main mash*, which has undergone acid and/or protein rests. The increased temperature of the adjunct mash might increase the main mash temperature to saccharification temperatures, but sometimes the main mash must be heated as well.

Cereal mashing is used to make beers which contain unmalted adjunct grains, assuming the brewer starts with raw grains, rather than pre-gelatinized grain flakes or grits.

Advantages: * As for Step Mashing. * *Allows the use of inexpensive raw grains* such as maize or rice which require high gelatinization temperatures (as opposed to pre-gelatinized grain flakes or grits).

Disadvantages: ** As for Step Mashing. * Time and energy intensive.* * Cereals must be boiled or hot-flaked before adding to mash. * Only appropriate for brewing beers which have a high proportion of adjunct grains.

Describe 3 Mash Techniques

A) Infusion Mash: Describe: Mixing grain w. single temperature of water & resting at that temp for the entire mash. **Adv. & Disadv.:** Requires minimum of labor, equipment, energy & time. Prevents use of undermodified malt & limits use of adjuncts.

B) Step Mash: Describe: Mashing in w. a low temp. of water. Raise mash temp. to achieve conversion goals by adding boiling water to mash or directly/indirectly heating mash tun. **Adv. & Disadv.:** Allows flexibility in use of different temp steps. Allows use of undermodified malts. Req. more resources (labor, time, equipment).

C) Decoction Mash: Describe: 1. Dough in. 2. Remove a thick third of mash. 3. Raise decoction briefly to saccharification temp. 4. Boil decoction 15-30 minutes, stirring constantly, adding water to avoid scorching. 5. Mix decoction back into main mash to raise temp. 6. Repeat up to 3 times. **Adv. & Disadv.:** Explodes starch granules. Breaks down protein matrix in undermodified malt. Improves extraction efficiency Promotes formation of melanoidins. Caramelizes sugars. Allows brewing without thermometer. Most labor & time intensive. Requires extra equipment. Risk of scorching decoction. May extract higher levels of tannins & DMS precursors from grain husks.

Question T11 "Diastatic and Proteolytic Enzymes" Sample Answer

	Proteolytic	Diastatic	
Works on:	Proteins	Starches	
Subset	Proteolytic	Beta Amylase	Alpha Amylase
Temp.	113-127 °F	130-150 °F	149-158 °F
Describe/ Explain	* Proteinase breaks down proteins into smaller fractions such as polypeptides – necc. for good head retention. * Peptidase breaks down polypeptides into peptides & amino acids, essential for proper yeast growth & development	* Starches are gelatinized	
		* Beta amylase enzymes breaks off maltose units from reducing ends of starches * Unable to break down largest units of starches * Denatured above 154 °F	* Alpha amylase enzymes breaks 1-4 links from starches at random * Unable to break down into smallest units of starches * Denatured above 167 °F
Effects	* Reduces cloudiness * Too long a protein rest can reduce head & body.	* Creates more fermentable wort, thinner bodied beer	* Creates more dextrinous wort, thicker bodied beer

Question T13 "Mashing" Sample Answer

Mashing Step	Temp.	Time	Active Enzymes	Description
Milling Grain	n/a	n/a	n/a	Grinding grain to crush kernels & expose starches
Dough-in	10-15 °F < than 1st rest			* Mixing grist w. water * 1.3 qt./ lb. grist * Break all clumps so no dry grist remains
Acid Rest	95-120 °F	60-120 min.	* Phytase	Breaks down phytin in grain husks, producing phytic acid, Mg++ & Ca++. Reduces mash pH in pale, undermodified grains & low Ca++ water. Creates yeast nutrients. Not necc. w. modern malts, proper water treatment.
Beta Glucanase/Starch Rest	~110 °F		Betaglucanase	For under-modified malt only. Reduces hemicellulose & gums (Beta glucans) in cell walls which can contribute starch haze & cause stuck mash.

Ferulic Acid Rest	~110 °F	15 min.	n/a	At pH < 5.7. Liberates ferulic acid, precursor to 4-vinyl guaiacol. Slightly aids prod. of clove flavor for German wheat/rye beers (but yeast strain & ferment. temp. more important). Not necc. for other styles.
Protein Rest	113-127 °F	15-60 min.	Proteinase & Peptidase = Proteolytic enzymes	Breaks down proteins into smaller fractions such as polypeptides. Breaks down polypeptides into peptides & amino acids, essential for proper yeast growth & development. Aids head form. & retent. Reduces risk of stuck mash.
Saccharification	* Breaks down starches into dextrins & fermentable sugars. Produces: * Monosaccharides: Glucose, Fructose, Mannose, Galactose * Disaccharides: Maltose, Isomaltose, Fructose, Melibiose, Lactose * Trisaccharides: Maltriose * Oligosaccharides: "dextrins" = glucose chains.			
Beta Amylase	130-150 °F	15-90 min.	Beta Amylase	* Subset of Diastatic enzymes * Yields wort very low in dextrins, high in fermentables * Breaks maltose units from reducing ends of starches. *Works slower than Alpha Amylase
Alpha Amylase	149-158 °F	15-30 min.	Alpha Amylase	* Yields wort high in dextrins, lower in fermentables * Randomly breaks 1-4 links from starches.
Mash-Out	168-172 °F	5-15 min.		* Denatures enzymes, stops conversion * Reduces viscosity, aids run-off of mash. * Reduces risk of stuck mash.

Technical Question T14. "All Grain Recipe"

Provide a complete ALL-GRAIN recipe for a <STYLE>, listing ingredients and their quantities, procedure, and carbonation. Give volume, as well as original and final gravities. Explain how the recipe fits the style's characteristics for aroma, flavor, appearance, mouthfeel, and other significant aspects of the style.

Styles may include: American IPA, Belgian Tripel, Bohemian Pilsner, Classic American Pilsner, Doppelbock, Dry Stout, English Pale Ale, German Pilsner, Oktoberfest, Robust Porter, Weizen.

10%	**Target statistics (starting specific gravity, final specific gravity, and bitterness in IBUs or HBUs) and color (as SRM or a textual description of the color).**
20%	**Batch size, ingredients (grist, hops, water, and yeast) and their quantities.**
35%	**Mashing, boil, fermentation, packaging, and other relevant brewing procedures.**
35%	**Explain how the recipe fits the style's characteristics for aroma, appearance, flavor, mouthfeel, and other significant aspects of the style; and describe how the ingredients and processes used impact this style.**

How to Design Your Recipes for the Exam

* Keep target statistics within the midpoint of the style descriptions.

* **Assume 5 gallon batches** (or whatever size you're most comfortable with) and calculate all quantities based on that target.

* **Keep recipes simple.** You're not trying to win a medal.

* **Use, or at least mention, proper ingredients for the style** (e.g., "Bohemian Pilsner was traditionally made using undermodified continental Pilsner malt").

* **Use, or at least mention, traditional techniques for brewing the style** (e.g., "Bohemian Pilsner was traditionally made using a triple decoction mash.")

*** Understand, and mention, why each ingredient is used in a particular beer.** (e.g., "Burton-style water, with its high sulfate levels, increases alpha acid extraction rates from hops, increasing hop bitterness.")

* **Understand, and mention, what each ingredient contributes to the finished beer** (e.g., "Pilsner malt produces a light-colored beer with bready, cracker-like aromas and flavors and possibly hints of DMS or hydrogen sulfide.")

* **Describe each ingredient** - grain, hops, water, yeast, adjuncts.

- At least describe quantities and basic ingredient type (e.g., "7.5 lbs. pale malt").

- Better yet, give as much detail as possible about the ingredient as possible (e.g., "7.5 lbs. of 5 °Lovibond Thomas Fawcett™ Maris Otter English pale malt" or "7.25 gallons of mash water, adjusted to have at least 350 mg/l Ca++ and 150 mg/l SO_4-, heated to a strike temperature of 175 °F.")

- Mention specific brands of ingredients if appropriate. E.g., Wyeast 1056 American Ale Yeast, Lyle's Golden Syrup.

* Understand, mention and describe each step of the brewing process, why each step is done and how it should be controlled.

- The steps in the brewing process are: Milling, Mashing, Sparging/lautering, Boiling, Cooling, Fermenting, Conditioning/lagering, Packaging.

- At minimum, describe the process. E.g., "After wort boil ends, crash cool wort."

Calculating Final Gravity

Final gravity is based on fermentability of the wort, but primarily yeast attenuation. Since most yeast strains attenuate to about 75%, a rough formula for F.G. is:

((OG -1) - ((OG - 1) x A) +1) = FG

The recipe discussion assumes 1.050, so ((1.050 – 1) - ((1.050 - 1) x .75) +1) = 1.0125, which is rounded down to 1.010. Beers with less attenuable worts and/or lower attenuating yeast strains use 1.016 instead.

- Better yet, describe exact techniques and purposes for each step. E.g., "After wort boil ends, crash cool wort using a counterflow chiller or heat exchanger to precipitate cold break, which keeps unwanted proteins and fatty acids from getting into your wort. Crash cooling also limits exposure to airborne pathogens before yeast is pitched."

* **Mention formulas if appropriate** (e.g., W x A x U x 7489 / V x C = hop utilization formula)

* **Mention common potential brewing or technique faults.** (e.g., "High levels of esters are wrong for this style, avoid by fermenting at cool end of the yeast's temperature range.")

* **Mention potential overlap with other styles** (e.g., "Similar to a German pilsner, but darker in color, sweeter, not as hoppy, and with a hint of DMS in the aroma.")

Basic Recipe Design

This section discusses the basics of recipe design for the test. It is based on Al Boyce's BJCP for Dummies exam prep guide, which was a very common preparation guide for the "legacy" BJCP exam. For this reason, most graders are very familiar with "Boyce method" recipes and are somewhat prejudiced against it. If used properly, this recipe design section will give you a score in the 70-85% range, but no higher. **Use it only if you don't have the time or resources to design your own recipes.**

If you do have time, work with your favorite basic brewing text and supplemental books such as ***Brewing Classic Styles*** and ***Designing Great Beers***. It's also helpful to play with various brewing software programs, since you can instantly see how changing ingredient types and quantities will change your recipe.

1) Vital Statistics

Use the following information to set up the vital statistics for your recipe:

O.G.: Original Gravity is 1.050 for "table strength" beers, 1.075 for strong beers - American IPA, Belgian Tripel and Doppelbock. **Memorize "1.075" and "1.050."**

F.G.: Finishing Gravity is 1.010 for beers with medium to medium-light body, 1.016 for sweeter beers with medium-full to full body - Bohemian Pilsner, Oktoberfest, Robust Porter and Doppelbock. **Memorize "1.010" and "1.016."**

IBU: Bitterness (International Bitterness Units) is 40 for beers with medium to medium-high hop bitterness, 25 for beers with medium-low hop bitterness and 10 for beer with very low hop bitterness (i.e., Weizen). **Memorize "40-25-10."**

SRM: Color (Standard Reference Measurement) is 6 for dark gold beers, 25 for dark brown beers. The outliers are 5 (Gold) for German Pilsner and 7 (Amber) for Oktoberfest. Memorize "6-25" "7 Oktoberfest," "5 German Pilsner" (**Mnemonic: At 6:25, you ordered 7 Oktoberfests and 5 German Pilsners**).

Calculating Original Gravity

To find the potential original gravity for a beer recipe, you must know the diastatic power of the grains in your mash, the extract efficiency of your brewing setup and the weight of grains in your grist.

As a rule of thumb, however, pure sugars yield 46 "gravity points" per pound, pale malt yields about 33 gravity points per pound and amber and toasted malts yield about 20 points per pound. Roasted or brown malts and non-malted grains don't yield any gravity points on their own. Expressed as a formula:

OG = ((G x P)/V) x E

Where:

OG = Original gravity.
G = grains (in pounds)
P = gravity points for the grain type.
V = final wort volume.
E = Extract efficiency.

Grain Blends: If you use more than one type of malt in the grist, you must calculate the OG of each type of malt separately and sum the total.

The Basic Recipe Discussion assumes 10 pounds of grain which yield 330 gravity points, 5 gallons of wort, and 75% extract efficiency. So: ((10 x 33)/5) x 0.75 = 1.050.

Vital Statistics Table

This table lists numbers to use for each of the beers mentioned in the question. Outliers are in bold italic type.

STYLE	OG	FG	IBU	SRM
American IPA	1.075	1.010	40	6
Belgian Tripel	1.075	1.010	25	6
Bohemian Pilsner	1.050	1.016	40	6
Classic American Pilsner (CAP)	1.050	1.010	40	6
Doppelbock	1.075	1.016	25	6
Dry Stout	1.050	1.010	40	25
English Pale Ale (EPA)	1.050	1.010	40	6
German Pilsner	1.050	1.010	40	5
Oktoberfest	1.050	1.016	25	7
Robust Porter	1.050	1.016	40	25
Weizen	1.050	1.010	10	6

2) Batch Size

Choose 5 gallons. Mention that actual batch size might be a bit bigger (5.5 gallons) to allow for equipment losses.

Note: The rest of the Basic Recipe Design section assumes 5 gallon batches.

3) Grain Bill (AKA Grist)

Use the following information to describe the grist for your recipe. Note that if you have time and know what you're doing, you can specify specific products (e.g., 15 °L Weyermann CaraMunich malt, Munton's Maris Otter English Pale Malt).

Points per Gallon

Realistically, malts, sugars and grains vary in their extract efficiency.

Malt	FGDB%	Max PPG	Typ. PPG (75%)	PPG Steep
2-row lager	80	37	28	0
2-row pale ale	81	38	29	0
6-row pale	76	35	26	0
Barley, roast	55	25	19	21
Biscuit	75	35	26	0
Brown	70	32	24	8*
CaraPils	70	32	24	4*
Chocolate	60	28	21	15
Crystal 10-15 °L	75	35	26	14*
Crystal 120 °L	72	33	25	16
Crystal 15-40 °L	74	34	25.5	18
Crystal 60-75 °L	74	34	25.5	18
Flaked barley	70	32	24	0
Flaked Rice	82	38	38.5	0
Flaked wheat	77	36	27	0
Flaked, Oats	70	32	24	0
Munich	75	35	26	0
Patent	55	25	19	21
Rostmalz	70	32	24	21
Rye malt	63	29	22	0
Special B	68	31	23	16
Sugar, cane	100	46	46	46
Sugar, corn	92	42	42	42
Sugar, dextrin	100	40	40	40
Victory	75	35	26	0
Wheat malt	79	37	28	0

* Low extraction rates due to unconverted starches.

Data taken from **How to Brew**, p. 193.

Extract Efficiency: Mention 75% for grains, 100% for adjunct sugars. It's easy to remember and allows you to use 10 or 15 lbs. of grain to design a 5 gallon recipe. Note: Actual extract efficiency can vary.

Malt Amounts: Use 10 lbs. for all beers except for IPA, Tripel and Doppelbock, which use **15 pounds.** Multiply by the percentages given below to get the exact grain bill:

Malt Types: Use malts from the appropriate country for the style (e.g., German Pilsner malt). Remember that some form of pale malt ("base malt") forms the largest portion of the grist for virtually all beer styles. You should list your base malt first.

Malts Percentages: Use the following malt percentages for the various styles:

American IPA: 80% American 2-row pale ale malt, 15% 20 °L crystal malt, 5% 60 °L crystal malt. Alternately, just 100% American 2-row pale. **Memorize: 80-15-5.**

Belgian Tripel: 80% Pilsner malt, 20% light candi sugar. **Memorize: 80-20.**

Bohemian Pilsner: 100% Moravian Pilsner malt.

CAP: 75% American 6-row lager malt, 25% flaked maize. **Memorize: 75-25.**

Doppelbock: 100% Munich Malt.

Dry Stout: 65% English pale ale malt, 25% flaked barley (unmalted), 10% 500 °L black roasted barley (unmalted). Alternately: 3% °L 400 chocolate malt, 3% 500 °L patent malt, and 3% 400 °L unmalted roasted barley. **Memorize: 65-25-10.**

English Pale Ale: 90% English pale malt, 10% 60 °L crystal malt or 10% Lyle's Golden Syrup™. **Memorize: 90-10%.**

German Pilsner: 100% Pilsner malt.

Oktoberfest: 100% Munich malt. Alternately: 50% Munich malt, 45% pilsner malt, 5% 15 °L crystal malt. **Memorize: 50-45-5.**

Robust Porter: 80% English pale ale malt, 10% 40 °L Crystal, 5% 350 °L chocolate malt, 5% 525 °L black patent malt. **Memorize: 80-10-5-5.**

Weizen: 70% German wheat malt, 30% pilsner malt. **Memorize: 70-30.**

4) Hop Additions

Use the following information to describe the hops used for your recipe.

Alpha Acid (AA): A quick "cheat" is to always use 5%, regardless of hop type. It is better, however, to memorize a few simple hops which are appropriate to all the beer styles and make them 4% or 5% AA for flavor and aroma hops and 8 or 10% for bittering hops.

Hop Additions: Only use bittering, flavor and aroma additions for the exam. **Mention other techniques where appropriate** (e.g., first wort for Bohemian Pils, dry hopping when for English Pale Ale or American IPA).

Boil Time: Use 60 minutes for bittering hops, 15 minutes for flavor hops and 0 minutes ("at knockout") for aroma hops.

Utilization Rates: Mention 25% or 28% for bittering, 5% or 8% for flavor, 0% for aroma.

Hop Amounts: Choose 2 ounces of bittering hops for 40 IBU, 1 ounce for 25 IBU or ½ ounce for 10 IBU. If a beer is supposed to have hop aroma or flavor, use ½ to 1 ounce of flavor and/or aroma hops. Effectively, they're "free" in terms of utilization.

Hop Types: Choose hop varieties appropriate for the beer's country of origin or style. Where multiple types are possible, mention multiple varieties.

Belgium: Styrian Goldings or Strisselspalt.

England: East Kent Goldings, Fuggles.

Czech Republic: Mention "Czech-grown noble hops" or just say Saaz.

Germany: Mention "German-grown noble hops" or name one: Hallertauer Mittelfrüh, Spalt or Tettnang.

USA: Choose one of the "C Hops:" Cascade, Centennial, Chinook or Columbus. If you want to get fancy, mention one of the modern, "dual use," proprietary types, such as Amarillo, Citra or Warrior.

Suggested Hop Additions

This table lists suggested hop amounts and types for each beer listed in the question. Note that "East Kent Goldings is listed as "EKG," Hallertauer Mittelfrüh is listed as "HM" and Styrian Goldings is listed as "SG."

Style	Bitter	Flavor	Aroma
American IPA	2 oz. Centennial	1 oz. Chinook	1 oz. Cascade
Belgian Tripel	1 oz. SG	1 oz. SG	None

Bohemian Pilsner	2 oz. Saaz	1 oz. Saaz	1 oz. Saaz
CAP	2 oz. Cluster	1 oz. U.S. grown HM	1 oz. U.S.-grown Tettnang
Doppelbock	1 oz. Spalter	0.5 oz. Tettnang	None
Dry Stout	2 oz. EKG	None	None
EPA	2 oz. EKG	1 oz. Fuggles	1 oz. Fuggles
German Pilsner	2 oz. HM	1 oz. Tettnang	1 oz. Spalt
Oktoberfest	1 oz. HM	1 oz. HM	None
Robust Porter	2 oz. EKG	1 oz. Fuggles	None
Weizen	0.5 oz. HM	None	None

5) Water

Water Treatment: Water should be dechlorinated using filtration and adjusted to match the historical city (or a historic city) for the style. **M**ention levels of particular mineral ions if they are particularly high, low or important to the style (e.g., very low ion water for Plzen, high sulfate water for Burton-on-Trent).

Total Volume: **9 gallons of total water for all styles except IPA, Tripel or Doppelbock**, where water is increased by 50% to 13.5 gallons.

Strike Water: 3.5 gallons of strike water (increased by 50% to 5.25 gallons for IPA, Tripel or Doppelbock) at 163 °F for a mash temperature of 150 °F.

Sparge Water: 5.5 gallons of sparge water (increased by 50% to 8.25 gallons for IPA, Tripel or Doppelbock) at 168 °F.

Water pH: All water should be adjusted to pH 5.2 using phosphoric or lactic acid. **Use 3 tsp for most beers, increased by 50% to 4.5 tsp for IPA, Tripel or Doppelbock.** Mention that more acid (or buffer) might be needed when brewing with highly alkaline water (e.g., Burton, Dublin, London).

Water Treatment Type

Style	City	Mineral Ion Ranges
American IPA	San Francisco	Medium low CO_3, Low Ca, Cl, SO_4, Mg, Na.
Belgian Tripel	Brussels	Medium Ca & CO_3, medium-low SO_4, low Cl, Mg, Na
Bohemian Pilsner	Plzen	Very low overall ion levels. Use distilled or reverse osmosis water, cut 50/50 or 75/25 with medium hardness dechlorinated tap water.
CAP	St. Louis	Medium CO_3, med-low Cl, SO_4, low Ca, Mg, Na.
Doppelbock	Munich	High CO_3, medium-low Ca, low Cl, Mg, Na, SO_4.
Dry Stout	Dublin	High Ca, CO_3, medium-low SO_4, low Cl, Mg, Na.
EPA	Burton-on-Trent	Very high Ca, CO_3 & SO_4, medium-low Cl, Mg, Na.
German Pilsner	Munich	High CO_3, medium-low Ca, low Cl, Mg, Na, SO_4.
Oktoberfest	Munich	High CO_3, medium-low Ca, low Cl, Mg, Na, SO_4.
Robust Porter	London	High CO_3, medium Ca, Cl, Na, SO_4, low Mg.
Weizen	Munich	High CO_3, medium-low Ca, low Cl, Mg, Na, SO_4.

6) Yeast

Yeast Type: Choose ale or lager. Mention country of origin (e.g., German lager yeast, English ale yeast). If possible, or appropriate to the style, **mention specific yeast strain or brand** (e.g., Wyeast 3068 Weihenstephan Weizen yeast).

Starter Culture: Create 1.5 quarts of starter for ales, 4 quarts for strong ales, 3 quarts of starter for lagers and 7 quarts for strong lagers. Cell counts for ales should be about 175 million/liter for ales, 275 million/liter for strong ales, 300 million/liter for lagers and 500 million/liter for strong lager. If you want to be clever, and have the time to explain yourself, suggest underpitching yeast for weizen.

Aeration: Write "Use food-grade oxygen and a sintered airstone for 1 minute to deliver 10 ppm dissolved oxygen to the cooled wort."

Fermentation Temperature: Choose 55 °F for lagers, 65 °F for ales and 70 °F for Belgian Tripel. If you want to be

Calculating Hop Amounts

A simplified formula for figuring the weight of hops needed is:

$\text{Weight} = \text{IBU} \times V / (A \times U \times 7490)$

Where:

Weight = weight of hops in ounces.
IBU = target IBU level for your beer.
V = wort volume in gallons
A = Alpha Acid percentage of the hops.
U = Utilization efficiency.
7490 = This is a conversion factor from metric to English units.

The calculation for IBU (Rager method) is

$\text{IBU} = ((W \times A \times U \times 7462) / (V * (1+GA))$

If wort gravity > 1.050 GA = (Boil Gravity - 1.050)

Utilization Efficiency: Utilization efficiency depends on a number of factors, mostly boil time, but also wort pH, mineral levels in the wort and sugar concentration. Utilization of bittering hops ranges from 25-33%, 2-10% for flavor hops and 0-2% for aroma hops.

Hop Blends: If you add a blend of hops, you must determine the average level of alpha acids. If you add different types of hops at different times during the boil, you must determine their total contribution to alpha acid levels separately and sum the total.

The sample recipe section assumes IBU targets of 40, 25 or 10, 5 gallons of wort, 5% alpha acid level, a utilization of 25% for bittering hops and utilization levels of 0% for flavor and bittering hops. Calculations are then rounded to the nearest whole ounce.

For example, for a beer with 40 IBU: $40 \times 5 / (.05 \times .25 \times 7490) = 2.13$ oz (rounded to 2 oz.)

clever, and have the time to explain yourself, suggest fermenting weizen at 62 °F and gradually letting the temperature rise to 70 °F.

Yeast Information Table

Suggested brands are based on Wyeast, no insult intended to other yeast producers! Outliers are in bold italic text.

Style	Brand	Cell count (mill/l)	Starter	Temp.
American IPA	American Ale	275	4 qt.	65 °F
Belgian Tripel	Abbey Ale	275	4 qt.	70 °F
Bohemian Pilsner	Budjevoice Lager	300	3 qt.	55 °F
CAP	American Lager	300	3 qt.	55 °F
Doppelbock	Munich Lager	500	7 qt.	55 °F
Dry Stout	Irish Ale	175	1.5 qt.	65 °F
EPA	London Ale	175	1.5 qt.	65 °F
German Pilsner	Munich Lager	300	3 qt.	55 °F
Oktoberfest	Munich Lager	300	3 qt.	55 °F
Robust Porter	London Ale III	175	1.5 qt.	65 °F
Weizen	Weihenstephan weizen	175	1.5 qt.	65 °F

7) Mashing

Mash Type: Choose the proper mash type for the style you wish to brew.

If you can’t remember the details for the appropriate mash type, choose Single Infusion, but mention and describe the appropriate traditional (or modern commercial) method of producing the beer and give justification for your choice. For example: “X is the classic mash technique for this style, but due to the highly modified malts available today, this recipe uses a single infusion mash.”

Rests: Unless you specified a Single Infusion Mash, mention types of rests and rest temperatures associated with the traditional forms of mashing.

Acid Rest: 95-120 °F for 60-120 minutes.

Protein/Beta-Glucanase Rest: 122 °F for 20 minutes.

Saccharification Rest - Beta Amylase: 130-150 °F for 30-90 minutes. Mash at this temperature for thinner-bodied, drier beers, e.g., EPA, Pilsners, American IPA.

Saccharification Rest - Alpha Amylase: 149-158 °F for 30-90 minutes. Mash at this temperature for fuller-bodied beers, e.g., Doppelbock, Oktoberfest.

Mash Out: 168 °F for 15 minutes.

Strike Water Temperature & Volume: Discussed under Water.

Mash Water Acid and Mineral Adjustments: Discussed under water (should be 3.5 or 5.25 gallons). Mash pH should be 5.2. Regardless of style, mash water should have 50 mg/l of calcium for optimal mash efficiency.

Special Ingredients: Tripel uses Candi Sugar, which is added to the boil, not the mash. CAP made using a cereal mash would use ground corn or rice, rather than flaked corn.

Recirculation (AKA Vorlauf): You should recirculate the mash runoff back through the mash bed in order to clarify the runoff for 30 minutes. Avoid splashing or spraying the runoff to avoid hot side aeration.

Sparging (Lautering): You mentioned sparge water volume back in the water section (5.5 or 8.25 gallons). Sparge water temperature should be **168 °F** and should last **for 45 minutes**. To avoid extracting tannins from your grist, **stop collecting runoff if the mash pH goes above 5.8 or the specific gravity of the runoff goes below 1.008.**

Calculating Water Volume

To find the volume of water needed for mashing and sparging you must know the mass of grain to be mashed and the target volume of the wort to be collected.

Mash Water Formula: The formula for mash water volume is:

Mass weight (lbs.) x 1.25 quarts = Wort volume (gallons).

Total Water Volume Formula: The formula to find the total volume of water needed for mashing, sparging and wort boiling is:

(Batch Volume + Trub Volume)/ (1 - ((Wort Shrinkage Percent/100)/ 1 - (Boil Time x (Boil-off Percentage/100)) + Equipment Loss Volume + Grain Volume) x Absorption Rate) = Total Water Volume.

The sample recipe section assumes a 5 gallon batch, with .5 gallons of trub, 4% wort shrinkage, 1 hour boil time, 10% boil-off, 1 gallon of equipment loss volume, 10 lbs. of grain and an absorption rate of = .13.

Sparge Water Volume Formula: The formula to find the amount of sparge water needed is:

Total Water needed – Mash Water = Sparge Water Volume

Mash Type Table

Style	Mash Type	Rests
American IPA	Step	Beta Amylase > Alpha Amylase > Mash Out.
Belgian Tripel	Step	Saccharification > Mash Out
Bohemian Pilsner	Triple Decoction	Acid Rest > Saccharification > Mash Out.
CAP	Cereal Mash	Protein > Saccharification > Mash Out
Doppelbock	Double Decoction	Protein > Saccharification > Mash Out.
Dry Stout	Single Infusion	Saccharification
EPA	Step	Saccharification > Mash Out
German Pilsner	Double Decoction	Protein > Saccharification > Mash Out.
Oktoberfest	Double Decoction	Protein > Saccharification > Mash Out.
Robust Porter	Single Infusion	Saccharification
Weizen	Triple Decoction	Protein/Beta-Glucanase > Saccharification > Mash Out

8) Wort Boiling, Cooling and Transfer

Boil Time: A 60 minute, full, rolling boil in an open kettle to facilitate hot break., except for beers where extensive hop extraction or color development is desired (American IPA, Doppelbock, Oktoberfest), in which case specify a 90 minute boil. For styles which use Pils malt or corn, mention that this process drives off DMS.

Hop Additions: Bittering hops added at the beginning of the boil. Flavor hops added at 30 minutes before the end of the boil. Aroma hops added at the end of the boil.

Finings: For all but weizen, 1 tbsp of Irish moss (or similar kettle finings) added 5-15 minutes before the end of boil in order to help precipitate the hot break.

For weizen: "No finings added due to desired cloudiness in finished beer."

Chilling: Crash cool the wort using a counterflow wort chiller or heat exchanger in order to precipitate the cold break. Wort should be cooled to approximately 5 °F below desired fermentation temperature.

Wort Transfer: Wort should be whirlpooled, filtered or siphoned to avoid transferring trub (hot and cold break, hop residue) to the fermentor. Some cold break is acceptable in the wort since it is necessary for optimum yeast health.

Fermentation

Yeast Strain, Volume, Temperature, etc: See Yeast, above.

Primary Fermentation Time: Ales: 3-5 days. Strong Ales: 7-14 days. Lagers: 2-4 weeks. Strong Lagers: 3-6 weeks.

Secondary Fermentation Time: Ales: None (for cask-conditioned English ales), otherwise 1-3 weeks. Strong Ales: 2-4 weeks. Lagers: Diacetyl Rest at 65 °F for 2-3 days. Conditioning for 2-4 weeks (6-8+ weeks for strong lagers).

8) Packaging

Bottle Conditioning: A quick and simple "boilerplate" answer to this part of the question is to just write, "Add ¾ cup of corn sugar at bottling or force carbonate to achieve 2.5 volumes of CO_2."

A better approach is to adjust bottle conditioning methods to the exact style, as listed below.

Style	Vol. CO_2	Carbonation method
American IPA	2.5	115 g (4 oz.) corn sugar
Bohemian Pilsner	2.5	115 g (4 oz.) corn sugar*
CAP	2.5	115 g (4 oz.) corn sugar
Doppelbock	2.5	115 g (4 oz.) corn sugar*
German Pilsner	2.5	115 g (4 oz.) corn sugar*
Oktoberfest	2.5	115 g (4 oz.) corn sugar*
Belgian Tripel	3.0	150 g (5.5 oz.) corn sugar
Weizen	3.0	150 g (5.5 oz.) corn sugar*
Dry Stout	2.0	75 g (2.6 oz.) corn sugar
EPA	2.0	75 g (2.6 oz.) corn sugar
Robust Porter	2.0	75 g (2.6 oz.) corn sugar

* Use of speise (wort at high kräusen from another, similar batch of beer) is traditional.

9) Explaining How the Recipe Fits the Style

* Mention the most important attributes first. (e.g., hop character for the American IPA).

* **Aroma:** Comment on malt, hop and yeast aroma (e.g., esters, phenols, diacetyl, DMS, sulfury notes, acetaldehyde), as well as other aromatics.

* **Appearance:** Comment on color, clarity and effervescence (e.g., sparkling, still), as well as head size, retention, color and texture. If appropriate, mention viscosity or alcohol "legs."

Color Calculations (Mosher, Daniels Formulae)

A rough and ready method of calculating beer color is as follows:

MCU = sum of (°Lovibond rating x pounds)/gallons

Once you've gotten MCU, you then need to correct the formula:

MCU < 10.5 SRM, the MCU rating is reasonably accurate.

MCU => 10.5- =>37 use Ray Daniels' formula to get actual SRM 10.5 to 15.8

MCU >37 MCU, use Randy Mosher's formula to get SRM 15.8 and higher.

Ray Daniels' formula: SRM = (MCU x 0.2) + 8.4 (Use this for Doppelbock on exam).

Randy Mosher's formula: SRM = (MCU x 0.3) + 4.7(Use this for Stout and Robust Porter on the exam)

Example: Tripel, 15 lbs 1.8 L Pilsner malt, (15 x 1.8) / 5 = 5.4 MCU = 5.4 MCU = 5.4 SRM.

Example: Doppelbock (8 lbs 10 L Munich malt, 8 lb 4 L Vienna Malt, Color = (8 x 10) + (8 x 4) / 5 = 22.4 MCU, 22 > 10.5 and < 37. Use Daniels 22.4 x .2 + 8.4 = 12.88 SRM.

Example: Dry Stout 8 lbs 2 L 2 row malt, 1 lb 400 L Roasted Barley, 1 lb 1 L Flaked Barley SRM = ((8x2)+(1x400) + (1x1))/5 x = 83.4 MCU. Use Mosher 83.4 x.3 + 4.7 = 29.72 SRM.

Example: Robust Porter 8 lb English pale 2 row malt 2L 1 lb crystal malt 60L 0.75 lb chocolate malt 350L 0.25 lb black patent malt 400L SRM = ((8x2) + (1x60)+(.75x350) +(.25x400))/5 = 87.7 MCU, Use Mosher 87.7x.3 + 4.7 = 31.01 SRM

* **Flavor:** Comment on malt flavor, sweetness or dryness, hop bitterness, hop flavor, yeast character (e.g., esters, phenols, diacetyl, DMS, sulfury notes, acetaldehyde), balance (sweetness vs. hop bitterness) and finish/aftertaste.

* **Mouthfeel:** Comment on body, carbonation level, alcohol character (e.g., warming, prickly, burning), texture (e.g.,

Calculating Strike Temperature

Strike Temperature Formula: When using an infusion mash, you must know the "strike temperature" for your water to achieve a particular target temperature before you add it to the mash. The formula is:

(0.2 ÷ R) X (T2 – T1) + T2 = Tw

Where:

Tw = actual temperature of infusion water
R = Ratio of water to grain in quarts per pound.
T1 = Initial mash (or dry grain) temperature.
T2 = Target mash temperature.

The sample recipe discussion assumes 1.25 quarts/lb. of mash, a mash temperature of 70 °F, a target temperature of 150 °F. So (0.2 ÷ 1.25) x (150 – 70) + 150 °F = 162.8 °F (rounded to 163 °F) creaminess), astringency, and other palate sensations.

- **If a beer doesn't have a particular characteristic, say so!** (e.g., "Alcohol warmth is inappropriate for this style").

10) Describe How ingredients & Process Affect Style

* If you're running out of time, a quick cop-out is to just write, "The malt, hops, and yeast used in this recipe work together to produce the aroma, appearance, flavor and mouthfeel representative of an X style beer." But, if you use this boilerplate text expect the graders to recognize it for the B.S. it is, and grade accordingly.

* A better way to answer is to briefly describe what each ingredient adds to the final beer, hitting the most import aspects first. For example for a German Pils, a good answer might be, "IBU levels, and Noble German hops (Tettnang and Spalt), used for flavor and aroma, give the beer firm bitterness, and the moderate to high elegant floral, spicy notes expected for this style."

* If you've got extra time at the end of the test come back to this part and elaborate, if you know it.

Question T14 Sample Recipe Sheet

This is a sample recipe sheet for question T14. You should practice using it to design sample recipes. Before the exam begins, if the exam organizer allows you to do so, write out as much of the form as you can remember and then fill in the blanks once you know what style you're being tested on.

Style:	Category:	Subcategory:	
Batch Size: 5 Gallons			
Vital Statistics			
OG:	IBU:	FG:	SRM:
Grist (@ 75% efficiency)	**Amount**		
Base Malt:	______Lbs.		
Other Malt: _________ °L	______Lbs.		
Other Malt: _________ °L	______Lbs.		
Other Malt: _________ °L	______Lbs.		
Other fermentables:	______Lbs.		
Hops (all @ 5% AA)	**Amount**	**Utilization**	**Boil**
Bittering:	______Oz.	25%	60 min.
Flavor:	______Oz.	5%	30 min.
Aroma:	______Oz.	0%	at flame-out
Mash hopping? Y/N			
Dry hopping? Y/N			
Water	**Volume**		
Total Volume:	_______gal.		
Mash Volume	_______gal.		
Sparge volume:	_______gal.		
Acid:	_______tsp.		

Water adjusted to: (City name)			
Important ion adds: Cl, CO_3, Ca, Mg, Na, SO_4			
Yeast			
Variety:	Starter volume:	1.5, 3, 4 or 7 qt.	
Aeration: 2 min. w/ food-grade O2 & sintered airstone to get 10 ppm dissolved O_2			
Fermentation Temp. __________ºF			
Mash			
Mash Type: Infusion.			
Traditional Mash Type: Step, Decoction, Cereal.			
Strike Water Temp.	__________° F		
Traditional Rests	Mash temp.	Time	Purpose
1.	__________° F	_____ min.	
2.	__________° F	_____ min.	
3.	__________° F	_____ min.	
Mash Out Y/N	168 °F	15 min.	
Recirculate/Vorlauf:	168 °F	30 min.	
Sparge/Lauter:	168 ºF	45-90 min.	
Boil: Boil 90 min. Full rolling boil to facilitate hot break, add hops according to schedule above.			
Finings: 1 tsp Irish moss added 15 minutes before flame-out to precipitate hot break.			
Chill: 1. Use counterflow chiller to crash cool wort to facilitate cold break. 2. Cool to 5 °F below fermentation temp. before pitching yeast. 3. Siphon, whirlpool or filter to separate wort from most of the cold break.			
Fermentation:	**Temp.**	**Time**	
Primary:	__________° F	___days/weeks.	
Diacetyl Rest:	__________° F	___days/weeks.	
Secondary:	__________° F	___days/weeks.	
Packaging: Bottle condition with ¾ cup corn sugar for priming			
Aroma:			
Appearance:			
Flavor:			
Mouthfeel:			
Impact of ingredients & procedures on style?			

T9. Gypsum, Fining & Krausening Question

`Discuss the following brewing techniques. How do they affect the beer? (a) adding gypsum, (b) fining, (c) kräusening.`

A. Adding gypsum: Accomplishes 2 things: increasing Ca++ and SO4--; Calcium helps yeast metabolism in proper levels, and also allows the wort to acidify. It is also critical to proper enzyme function. Sulfate lends soft edge to hop bitterness by affecting alpha-acid extraction & creating a synergistic perception effect.

B. Fining: Addition of kettle finings (Irish moss) to coagulate proteins to clarify beer. May also be carried out post-fermentation (Isinglass, Bentonite, Polyclar) to help precipitate tannins and/or proteins that may cause haze, or even flavor instability.

C. Kräusening: The addition of a portion of actively fermenting wort to wort that has finished fermenting. Used chiefly as a means of providing "natural" carbonation. Also reduces residual diacetyl & may contribute acetaldehyde ("green" beer character) in the finished beer.

Kräusening is a German technique where a portion of actively fermenting wort (from another batch of beer at the high kräusen phase of the Fermentation stage of the yeast's life cycle) is added to green beer which has finished fermenting (where the yeast is at the Sedimentation stage of the yeast life cycle), just prior to packaging. This provides active, healthy yeast to supplement dormant/dying yeast lost during extended lagering. It is typically used when making German lagers or wheat and rye beers in order to comply with the Reinheitsgebot and to provide sufficient healthy yeast to properly bottle condition the beer. (Brewers who force carbonate their beer comply with the Reinheitsgebot by using carbon dioxide collected during yeast fermentation.)

Kräusening is often used by German commercial brewers who brew the same varieties of beer on a regular schedule. Even for those brewers who don't bother with the Reinheitsgebot, the practical benefit of kräusening is that they can top up the headspace in their conditioning tanks with kräusen once fermentation subsides, increasing the volume of beer in their tanks, reducing headspace and possibly freeing up tank space.

Typically, 10-20% of fresh wort is added depending on desired level of carbonation and batch size. For a 5 gallon batch of homebrew, this works out to 2-4 quarts. When homebrewers use this technique, they generally make a second yeast starter, sometimes using canned wort from the batch of beer to be kräusened, and add that to the green beer.

The practice of adding unfermented wort (speise) to carbonate finished beer is related to kräusening, but technically isn't the same thing.

Effects on Beer: *For brewers who wish to comply with the Reinheitsgebot, kräusening provides natural carbonation* for beer without adding sugar or artificial carbon dioxide. *Actively fermenting yeast helps scavenge VDK (diacetyl) & acetylaldehyde still present in the packaged beer, and also helps fully attenuate high gravity lagers.* Conversely, yeast in the *kräusen can also impart these off flavors* if they can't complete their fermentation in the bottle. *Kräusening can also result in infection* of the bottled beer, or the beer from which the kräusen came, if the brewer doesn't practice proper sanitation procedures. Finally, if the wort used to kräusen isn't identical to the beer to be kräusened, *the brewer must recalculate vital statistics* like ABV, IBU and SRM.

My Completist Answer to T9.

Describe	Effect on Beer
Adding Gypsum	Gypsum = Calcium Sulfate (CaSO4). * Part of "Burton salts." * Found naturally at high levels in Burton-on-Trent water. * Increases Ca++ and SO4-- levels. * Ca++: - Helps yeast metabolism in proper levels. - Lowers wort pH. - Interacts with phosphates in malt to form Ca3+(PO4)2 + 2 H+ ions, reducing residual alkalinity & mash pH. - 50+ ppm needed for proper mash enzyme function. * SO4: - Aids alpha acid extraction. - Increases perception of hop bitterness. - Imparts drying, bitter flavor in excess. - Can impart sulfury notes in excess. * Commonly used for English IPA & pale ales.
Finings	Compound added to wort or green beer to clarify it. * Electrostatically attracts charged suspended particles, making them flocculate, thus precipitating faster. * 50+ mg/l Calcium in H_2O necc. for finings to work. **Kettle/Copper Finings:** Irish moss (dried seaweed - Chondrus *Crispus*), carrageen or Whirlfloc^{TM} Added in last 15 minutes of boil. Helps to remove hot break - proteins responsible for protein/chill haze & flavor instability. **Cask/Fermenter Finings:** Added to Secondary Fermenter. Gelatin, Polyclar (PVP, polyvinyl pyrrolidone), Isinglass (dried, powdered swim bladders of fish - historically sturgeon, cod), Sparkloid^{TM} or Silica gel. Negatively charged. Coagulates suspended proteins and polyphenols (tannins) responsible for chill/tannin haze & flavor instability. Also aids yeast flocculation.
Kräusening	Adding a portion of actively fermenting wort (from another batch of beer at High Kräusen/Fermentation stage of yeast life cycle) to green beer which has finished fermenting (Flocculation/Sedimentation Stage), just prior to packaging. * Provides active, healthy yeast to supplement yeast lost during long lagering. * * Gives natural carbonation without adding corn sugar or artificial CO2, to comply w. Reinheitsgebot. * Actively fermenting yeast helps scavenge VDK (Diacetyl) & Acetylaldehyde. * Can help attenuate beer to lower FG. * Can contribute acetaldehyde ("green" beer character) and diacetyl to finished beer. * Possible source of infection (if other batch of beer infected). * Us. added at 2 qt. Kräusen/5 gal. beer.

Question T10 "Hot and Cold Break" Sample Answer

Meaning	What's happening? Why important?
Hot Break	* Flocculation of proteins and other materials during wort boil. * Begins forming at start of boil - 212 °F. * Removes proteins that cause chill haze & flavor instability. * pH 5.2 ideal. * Achieved by full, rolling boil of 60+ min. * 2 hr. boil = max. hot break. * Aided by quick temperature rise. * Controversy regarding removal during boil or not.

Cold Break	* Flocculation of proteins & other materials during wort cooling. * Begins at ~140 F. * Removes proteins & polyphenols (tannin) complexes responsible for chill haze & flavor instability. * Removes more carbohydrates than hot break. * Wort must be rapidly cooled below 70 °F max. cold break. * Reduces fusels & sulfur flavors. * Aids beer clarity. * Reduces DMS. * Some cold break must be let into fermenter to provide yeast nutrient.

Question T14 Sample Recipe Sheet

This is a sample recipe sheet for question T14. You should practice using it to design sample recipes. Before the exam begins, write out as much of the form as you can remember and then fill in the blanks once you know what style you're being tested on.

Style:	Category:	Subcategory:		
Batch Size: 5 Gallons				
Vital Statistics				
OG:	IBU:	FG:	SRM:	
Grist (@ 75% efficiency)	Amount			
Base Malt:	______Lbs.			
Other Malt: _________ °L	______Lbs.			
Other Malt: _________ °L	______Lbs.			
Other Malt: _________ °L	______Lbs.			
Other fermentables:	______Lbs.			
Hops (all @ 5% AA)	Amount	Utilization	Boil	
Bittering:	______Oz.	25%	60 min.	
Flavor:	______Oz.	5%	30 min.	
Aroma:	______Oz.	0%	at flame-out	
Mash hopping? Y/N				
Dry hopping? Y/N				
Water	Volume			
Total Volume:	_______gal.			
Mash Volume	_______gal.			
Sparge volume:	_______gal.			
Acid:	_______tsp.			
Water adjusted to: (City name)				
Important ion adds: Cl, CO_3, Ca, Mg, Na, SO_4				
Yeast				
Variety:	Starter volume:	1.5, 3, 4 or 7 qt.		
Aeration: 2 min. w/ food-grade O2 & sintered airstone to get 10 ppm dissolved O_2				
Fermentation Temp.				
__________°F				
Mash				
Mash Type: Infusion.				
Traditional Mash Type: Step, Decoction, Cereal.				
Strike Water Temp.	__________°F			
Traditional Rests	Mash temp.	Time	Purpose	
1.	__________°F	_____ min.		
2.	__________°F	_____ min.		
3.	__________°F	_____ min.		
Mash Out Y/N	168 °F	15 min.		
Recirculate/Vorlauf:	168 °F	30 min.		
Sparge/Lauter:	168 ºF	45-90 min.		
Boil: Boil 90 min. Full rolling boil to facilitate hot break, add hops according to schedule above.				
Finings: 1 tsp Irish moss added 15 minutes before flame-out to precipitate hot break.				
Chill: 1. Use counterflow chiller to crash cool wort to facilitate cold break. 2. Cool to 5 °F below fermentation temp. before pitching yeast. 3. Siphon, whirlpool or filter to separate wort from most of the cold break.				
Fermentation:	Temp.	Time		
Primary:	__________°F	___days/weeks.		
Diacetyl Rest:	__________°F	___days/weeks.		
Secondary:	__________°F	___days/weeks.		
Packaging: Bottle condition with ¾ cup corn sugar for priming				
Aroma:				
Appearance:				
Flavor:				
Mouthfeel:				
Impact of ingredients & procedures on style?				

T15. Malt and Yeast Question

This question addresses two separate ingredients, malt and yeast. Please provide the following information in your answer:
(1) Identify and describe the different types of malts by their color and the flavor they impart to the beer, and give at least four distinct styles with which specific malts are associated.
(2) Provide five distinct considerations in selecting the appropriate yeast strain for a given beer style.

25%	Identify types of malt.
35%	Identify types of malt associated with at least four beer styles

40%	Provide five distinct yeast strain selection considerations

Question T15 "Malt and Yeast" Sample Answer

Terminology

° ***Lovibond (°L):*** Measure of malt & beer color used by U.S. brewers, ranging from . Roughly corresponds to SRM (Stand. Reference Measurement). °EBC (European Brewing Convention) = ~ °Lovibond x 2. Color scale for Lovibond ranges from 0° (clear) to 500°+ (black).

° ***Lintner:*** Measure of diastatic power, the ability of the malt to fully convert its starches, used by U.S. brewers. Ranges from 0° (no diastatic power) to 150°+ (excessive diastatic power, typical of "hot" American 6-row lager malts designed to be used with adjunct grains). The European equivalent is °Windisch-Kolbach (abbreviated °W-K).

1. Pale Malt (AKA Base Malt)

Dried at 90 °F, kilned at 120-140 °F for 12-20 hours, cured at 175-185 °F for 4-48 hours.

Characteristics: * *Highest diastatic power* (40-150 °Lintner). * *Lightest color.* . * *Must be mashed.* * Some types have excess diastatic power and can be used to convert adjunct grains * Forms the majority of the grist for almost all beer styles. * *Color:* 1.8 - 4 °L (makes straw to golden color beer).

Flavor/Aroma: Bready, grainy, malty, sweet, sometimes slightly toasty.

Examples: American 2-row, American 6-row, Pilsner, English Pale, English Mild, Belgian Pale.

Associated Styles: All pale beers, e.g., American light lagers (American 6-row), Pilsner (Pilsner malt), English pale ale (English pale), Mild (Mild malt), American ales (American 2-row malt).

2. Amber/Toasted Malt

Dried at 90 °F, kilned at 120-145 °F for 12-20 hours. Cured at ~220 °F until proper color achieved.

Characteristics: * *Reduced diastatic power* but usually capable of self-conversion (i.e., converting own starches, but not adjunct grains, 20-40 °Lintner). * *Most must be mashed.* * *Adds color and complexity to beer.* * Usually forms 5-20% of grist for amber/copper-colored beers. * Can be made at home by toasting base malt. * Higher kilning temperatures produce melanoidins from amino acids and malt sugars. * *Color:* 4-70 °L (makes golden to dark amber beer).

Flavor/Aroma: Grainy, malty and sweet with hints of toast to bready, biscuity, crusty or toasty.

Examples: Vienna, Munich, Aromatic/Melanoidin (e.g., Dark Munich, Biscuit™, Victory™), Amber, Brown, Special Roast.

Associated Styles: All amber and brown beers, but especially malt-oriented styles, e.g., Vienna lager (Vienna malt), Oktoberfest (Munich malt), Bock (Munich, Vienna), California common, American brown ale, English brown ales, mild.

3. Crystal/Caramel Malt

Fully-modified, green malt is kilned at 50% moisture content at 150-170 °F for 1.5 - 2 hours without ventilation to "mash" starches within husk. It is then kilned at higher temperature to achieve desired color & flavors.

Characteristics: * *No diastatic power.* * *Can be steeped.* * Usually forms 1-5% (up to 10%) of grist to adjust color, mash pH, and/or to add aroma and flavor. * Different maltings produce unique products with distinct flavor profiles. * *Color:* 2-220 °L (makes golden to dark brown beer).

Flavor/Aroma: Sweet, caramel, honey, toffee, toasted, burnt sugar, dark fruit.

Examples: Dextrin, Crystal, Cara-™, malts, BruMalt™, Special B™.

Associated Styles: Sweet, full-bodied beers, especially Bock, Southern English brown, some Stouts (e.g., Russian Imperial Stout), strong Belgian ale, strong ales.

4. Roasted/Kilned Malts

After curing to 5% moisture, this malt is roasted at high temperatures (425-450 °F), for up to 2 hours, depending on the degree of roastiness desired.

Characteristics: * *No diastatic power.* * *Can be steeped.* * *Different flavors & properties due to special kilning techniques.* * Usually forms 5-10% of grist for color, body, complexity. * Typically undermodified (less than 50%) or made from non-premium malt. * No protein rest needed, since starches and proteins degraded by roasting. * Many have proprietary names. * Hard "glassy" texture to endosperm. * *Color:* 300-600 °L (makes dark brown to black beer).

Flavor/Aroma: Nutty, bittersweet, bitter, chocolate, coffee, roasted.

Examples: Chocolate malt, Rostmalz, Black/Patent malt.

Associated Styles: Dark beers, especially dark lagers, porter and stout.

5. Non-Barley Malts

A variety of malts made from grains other than barley, but processed using methods similar to those used for barley malt.

Characteristics: * Usually made in a manner similar to pale malt. * Often huskless. * Higher in proteins & gums, so more prone to stuck mash, haze & flavor instability. * Limited diastatic power, but pale malts are capable of self-conversion. * Unique flavor, aroma and texture characteristics. * Sometimes up to ~10% of grist to improve body, head retention, add complexity. * Forms 25-70% of grist in wheat/rye beers (must be 50+% by law for German wheat & rye). * Color: 2-3 °L for pale malts, up to 600 °L for darker varieties.

Flavor/Aroma: Dry, slightly sour, spicy, creamy, grainy. Darker versions can have amber/brown or roasted/kilned notes.

Examples: Wheat malt, Rye malt, Oat malt.

Associated Styles: Wheat & rye beers.

A) Malt types

Identify/Describe	Flavor	Styles
Base/Pale: * Dried @ 90 °F, kilned @ 12-140 °F for 12-20 h., Cured @ 175-185 ° F for 4-48 h. * Forms most of the grist for almost all beer styles. * Full diastatic power. * Must be mashed. * Ex. Amer. 2-row, Amer. 6-row, Pilsner, English Pale, Eng. Mild, Belg. Pale. * 1.8 - 4 °L straw, golden.	Grainy, malty, sweet, slightly toasty	Esp. pale beers: Light Lager, Pilsner, Pale ale.
Amber/Toasted: * Dried @ 90 °F, kilned @ 12-140 °F for 12-20	Grainy, malty,	Amber/Brown beers, esp.

h., Cured @ ~220 ° F until proper color achieved. * Reduced diastatic power, us. capable of self-conversion. * Most must be mashed. * Us. 5-20% of grist for color, complexity. * Ex. Vienna, Munich, Aromatic/Melanoidin (e.g., Dk. Munich, Biscuit™ , Victory™), Amber, Brown, Special Roast. * 4-70 °L - amber to brown.	sweet, toasty hints to bready, biscuity, toasted or bread crust	malt-oriented styles: Amber Lager, Bock, California Common, Brown Ale
Crystal/Caramel * Green malt heated to 150 - 170 °F for 2 h. in closed kiln to "mash" starches within husk. Kilned at higher temp. to get desired color & flavor. * No diastatic power. * Can be steeped. * Us. 5-10% of grist for color, body, complexity. * Many flavors & properties due to kilning techniques. * Ex. Dextrin, Crystal, Cara-™ malts, BruMalt™, Special B ™. * * 2-200 °L - straw dark brown.	Sweet, caramel, honey, toffee, toasted, burnt sugar, dark fruit.	Full-bodied beers, esp. Amber Lager, Bock, S. Eng. Brown, some Stouts (e.g., RIS), Strong Belgian Ale, Strong Ale.
Roasted/Kilned * Roasted @ high temp., up to 450 °F, for up to 2 h. * Ex. Chocolate, Rostmalz, Black/Patent. * Us. undermodified or made from lower-grade malt. * No diastatic power. * Can be steeped. * Us. 1-5% (up to ~10%) of grist to adjust color, mash pH, add aroma/flavor in dark beers. * 300 -600 °L - dk. brown-black.	Nutty, bittersweet, bitter, chocolate, coffee, roasted.	Dark beers, esp. Dark Lager, Porter, Stout.
Non-Barley * Ex. Wheat, Rye, Oat, etc. * Made in manner similar to pale malt. * Often huskless. * High in proteins & gums - prone to stuck mash, haze & flavor instability. * Low diastatic power, can self-convert. * Unique flavors, aromas and textures. * Us. up to ~10% of grist to improve body, head retention, add complexity. * 25-70% of grist in wheat/rye beers (=>50% by law for German wheat & rye). * 2-3 °L - straw, golden.	Dry, slightly sour, spicy, creamy, grainy	Wheat & rye beers, Oatmeal Stout

B) 5 Yeast Strain Considerations

Consideration	Effect
Apparent Attenuation	High attenuation (>75%) = Less residual sweetness, more alcohol, less body. Low attenuation (<70%) = more residual sweet, lower ABV, fuller body
Alcohol Tolerance	Better yeast health/performance in high gravity or high-alcohol wort. Most brewing strains OK to ~9% ABV, start struggling above that, can't go past ~15% without "feeding," aeration and other special techniques. Wild or non-brewing strains die above ~2-3% ABV.
Flocculation	High flocculation = Less time required for clearing, clearer beer, less need to filter, better bottom cropping. But, yeast might fall out of suspension too soon, leaving VKD/acetylaldehyde - might need to be roused. Poorly flocculant/"powdery" yeasts (e.g., Pride of Ringwood) must be removed by fining or filtration, don't crop well, but don't drop out prematurely. Historically, top vs. bottom cropping (AKA "top fermenting" vs. "bottom fermentation") for yeast propagation was a factor. Modern commercial brewers mostly bottom crop.
Fermentation Temp.	Higher temp = more esters, phenols, fusel oils, shorter fermentation time. Lower temp. = cleaner flavor & aroma, but slower working. Stress on yeast at low temp. can prod.VKD/acetylaldehyde and H2S. Diacetyl rest @ 50-60 °F for 1-3 days might be necc. Lager yeasts ferment 45-55 °F range, hybrids 55-65 °F, ale 60-75 °F (e.g., Scottish Ale vs. Trappist yeast). Lager and hybrid yeasts require special homebrewing equipment.
Ester, Phenol, Diacetyl Production	Esters = fruity, floral. Phenols = spicy, peppery, clove. Diacetyl = buttery, butterscotch, perception of fuller body. Not appropriate for many styles of beer. "Belgian" yeasts noted for spicy phenols and tree and tropical fruit esters (e.g., pear, cherry, guava, pineapple, bubblegum). American ale yeasts = relatively neutral - light apple esters. English ales = full fruity floral notes (pear, ripe apple, cherry). Lager = neutral, occasionally some light diacetyl (Bohemian) or sulfur (German) OK.